HAMPTON ROADS TRANSIT

U.S. Department of Transportation
Federal Transit Administration

Draft Environmental Impact Statement

VIRGINIA BEACH TRANSIT EXTENSION STUDY

Appendix K

Travel Forecast Results Report

February 2015

Cover image: courtesy of the City of Virginia Beach

Table of Contents

Appendices

1.0 Introduction

The purpose of this report is to provide a detailed description of the analysis method used in forecasting the daily ridership for all the transit alternatives considered in the Virginia Beach Transit Extension Study (VBTES). The ridership forecasts were developed by applying the Hampton Roads regional travel forecasting model, developed and maintained by the Virginia Department of Transportation (VDOT). VDOT, through its consultants, developed the base networks, coding, and other necessary seed files necessary for highway project prioritization and air quality conformity. The Hampton Roads Transportation Planning Organization (HRTPO), the local MPO, developed the socioeconomic inputs (in coordination with the local cities), and provided other local coordination and validation of the model. Hampton Roads Transit (HRT) provided VDOT and HRTPO with transit routes and schedules sufficient to develop the transit component of the model. The model set and its components are of the same type as those used in most large urban areas in North America. The structure of the model and the process of applying them to transportation studies are consistent with the method recommended by the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA).

Report Organization

The following sections are included in this report:

- **Section 2** presents a general description of the modeling methodology used along with key study assumptions.
- **Section 3** presents a brief summary of the initial review work conducted on the HRT's model, the steps that were recommended to go forward in the modeling effort, and the results of the model recalibration. Technical memoranda discussing this work can be found in **Appendices K-1, K-2, K-3, and K-4**.
- **Section 4** discusses the application of the calibrated model to generate the 2034 ridership forecasts for all of the VBTES alternatives.

2.0 Description of Travel Modeling Methodology

The ridership forecasts for the VBTES alternatives were developed by applying the Hampton Roads regional travel demand model using forecast year (2034) demographic and land use inputs. The regional travel demand model is a collection of computer-based supply and demand models that are executed sequentially. These models account for future study area population, projected employment in the Town Center area and other major activity centers, socioeconomic characteristics of study area residents, parking costs, travel time, and cost characteristics of the competing highway and transit modes of travel.

The model set simulates travel on the entire highway and transit system in the Norfolk-Virginia Beach area, incorporating all transit services (local bus, express bus, and The Tide) provided by HRT in the region. The model contains information on service frequency (i.e. how often trains and/or buses arrive at any given transit stop), routing, intermodal connections, travel time and transit fares for all transit

lines. The highway system includes all interstate highways and principal arterial roadways as well as minor arterial and local roadways. Outputs of the model set contain detailed information related to the transportation system. The model provides output data about highway characteristics such as traffic volumes, congested travel speeds, vehicle miles traveled, and average travel times on the roadway links. Transit information is provided by the model relating to the average weekday ridership on different transit sub modes (rail, local buses, express buses and commuter buses), station boardings, park-and-ride demand, and peak load volumes.

The basic structure of the model is based on the traditional method, which consists of a four-step, sequential process:

- trip generation
- trip distribution
- mode choice
- trip assignment

This process is used to estimate the average daily transit ridership, based on population and employment forecasts, projected highway travel conditions (including downtown parking costs) and projected transit service. **Figure 1** shows the key inputs, outputs and the sequential connection among the four steps.

The geographic area represented in the Hampton Roads regional model is divided into smaller areas known as traffic analysis zones (TAZs). All calculations in the travel model are performed at the TAZ level, which represents all of the population and employment within a given zone as one homogenous unit. There are approximately 1,063 such TAZs in the model. A brief description of the Four-Step process is given below.

Trip Generation

In the first step, the model estimates the number of trips produced in and attracted to each traffic zone. To accomplish this, the model uses estimates of projected population, employment, and other socioeconomic and household characteristics of each zone. Trips are classified into three major categories according to their purpose: home-based work trips (trips between home and places of employment), home-based other trips (trips to or from home for purposes other than traveling to employment, such as shopping or recreation), and non-home based trips (all trips that do not involve traveling to or from home). A trip generation model run is executed for each trip purpose. The output of the trip generation model feeds into the rest of the model chain. Therefore, great care is taken to ensure that the demographic and socioeconomic data are as accurate as possible to prevent the propagation of errors in the remaining model steps.

Trip Distribution

In the second step, the distribution model links the trip ends[1] estimated from trip generation to form zonal trip interchanges[2]. The output of this step is a trip table, a matrix containing the number of trips occurring between every origin-destination zone combination. Trip distribution is performed for each trip purpose. In a system of 1,063 zones, 1.13 million trip origin to destination combinations are possible.

Mode Choice

In this step, the mode choice model allocates the person trips estimated from the trip distribution step to the two primary modes: automobile and transit. This allocation estimates the desirability, or utility, of each choice a traveler faces based on the attributes of that choice and the characteristics of the individual. The resulting output of the mode choice model is the percentage of trips that use the automobile, transit, and fringe parking facility for each trip interchange. The transit trips are further divided into Walk Access transit trips and Drive Access (park and ride) transit trips. The fringe parking trips in downtown Norfolk are further divided into those who park at the fringe parking facility and walk to their destinations, those who park at the fringe parking facility and take transit to their final destinations, and those who park at the fringe parking facility and take shuttle buses to reach their final destinations. The auto trips are further divided into single-occupancy and multiple occupancy trips.

The mode choice model set consists of three models, one for each trip purpose. Inputs to the mode choice model, transit travel times and costs and highway travel times, socioeconomic data are supplied by the computerized transit and highway networks.

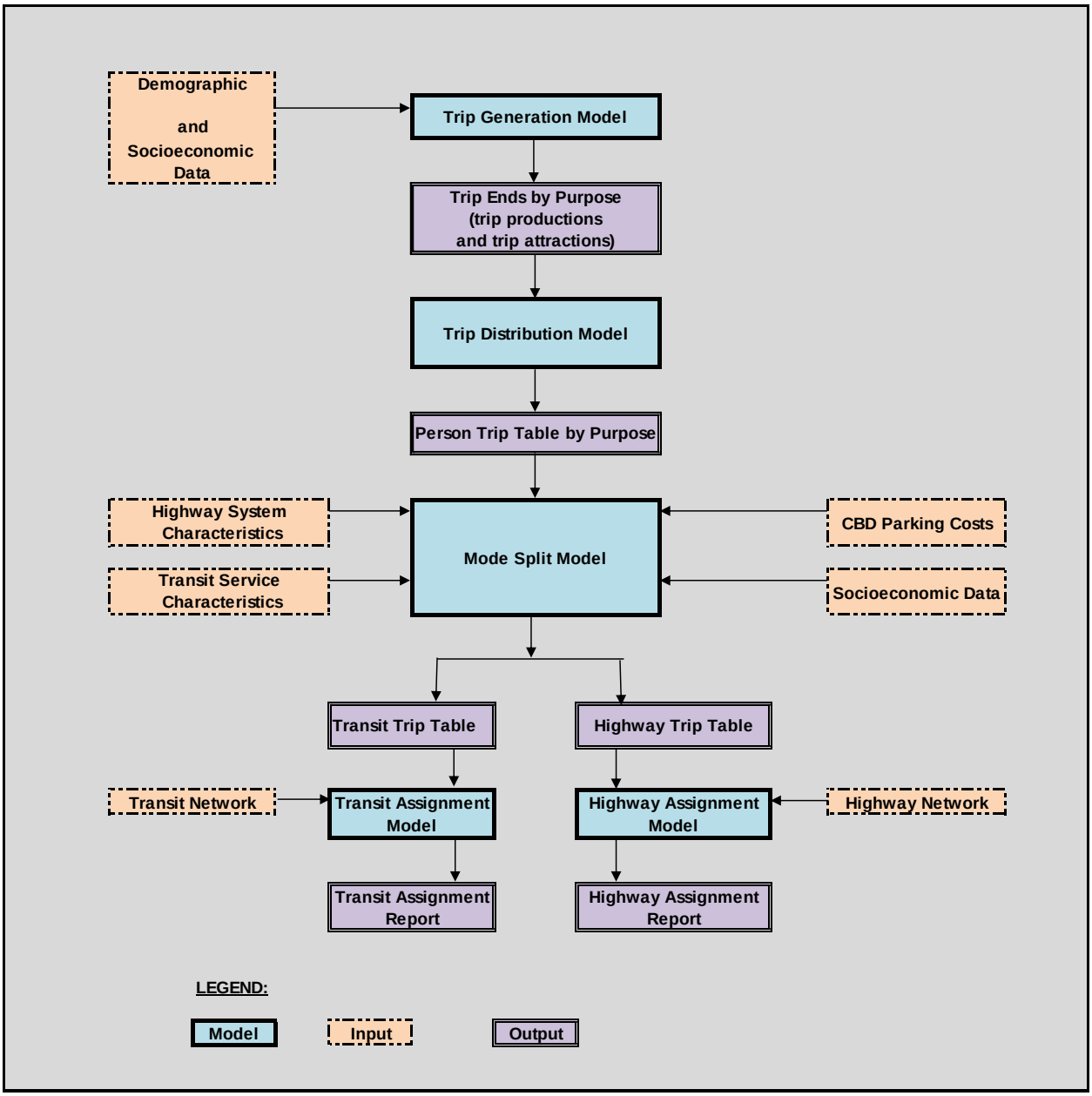
Trip Assignment

In this final step, the model assigns the transit trips to different transit modes such as local bus, express bus, and rail. The model uses all the available transit paths from one zone to another. This path may involve just one transit mode, such as local bus or express bus or multiple modes, such as local bus with a transfer to the rail line. Highway trips are assigned to the highway network. Thus, future year traffic volumes on highways and forecasted transit ridership on transit lines can be obtained from the model outputs.

Population and employment are key inputs to the demand forecasting process and are developed by HRTPO (Hampton Roads Transportation Planning Organization). The real cost of parking in downtown Norfolk was assumed to increase in the future. The future year transit fare structure is assumed to be similar to the current year fare structure. The models assume that people, as a rule, wish to minimize transfers, as well as minimize their overall cost of travel in terms of time and money.

[1] Trip ends represent the point from which the trip is produced or to which it is attracted.
[2] Movement between zones

Figure 1 | Four-Step Modeling Process



Source: HDR, Inc.

3.0 Model Review, Calibration, and Validation

3.1 Initial Review of the HRT Travel Demand Model

Prior to embarking on a full-scale model calibration and validation process, a thorough review of the base year HRT model was conducted in 2011 and 2012. This review identified that the VDOT regional model was consistently underestimating the demand for The Tide and the transit system as a whole. Based on that review, a set of recommendations were made in order to fine tune the model for New Starts application, including:

- Reviewing travel restrictions placed in the model (such as transfers between modes and how park and rides are used) to determine if they are valid based on observations from recent data collected on travel patterns
- Performing diagnostic tests on the model to determine if a major calibration of the transit assignment module is warranted
- Adjusting values of shadow prices for downtown and fringe parking based on existing parking utilization and constraints.

Three technical memoranda documenting the results of the review work conducted by HDR are in **Appendices K-1, K-2, and K-3** of this report. Close coordination with FTA's technical staff was maintained throughout the review process.

3.2 Calibration and Validation of the Ridership Model

After initial review of the transit demand model, HRT proceeded to calibrate and further validate the ridership model in response to FTA recommendations. The final calibrated model generated results that were in line with ridership of The Tide and buses based on travel surveys taken in 2011 and 2012. The calibration and validation report is attached as **Appendix K-4** of this report.

4.0 Development of Ridership Forecasts for the VBTES Using the Calibrated HRT Model

4.1 Model Application

For the Virginia Beach Transit Extension Study (VBTES), the forecast year (2034) transportation network was developed by including all the future highway and transit projects that were programmed in the Regional Transportation Plan. On the transit side, each transit alternative was coded in the computerized network by providing all the necessary information regarding the operational characteristics of the proposed service. This would include access characteristics at each station, peak and off-peak headways, station dwell times, travel times, proposed fares and intermodal connections. For each alternative, appropriate market areas (groups of zones on either side of the proposed alignment) were delineated for each station and proper transit access connections were coded.

Using the updated transit network information and other future year model inputs (such as population, employment and other socioeconomic data), the calibrated model set was run for each transit alternative. The daily transit ridership on the proposed transit service was obtained directly from the

model outputs. The model provides daily boardings and alightings at each proposed station by trip purpose and mode of access (park and ride versus walking to station or transferring from buses). Other important demand statistics such as linked transit trips in the system, vehicle miles and hours travelled by all modes of transportation, transit shares to CBD and non-CBD locations and boardings by transit sub modes can also be extracted from the model outputs.

After the model runs are completed, the results are used to summarize the projected number of forecast year daily boardings and parking demand at the station level. The ridership forecasts estimated by the travel demand models depend heavily on the input assumptions. Among those, the most important are:

- future population growth (based on MPO's 2034 forecasts),
- future employment growth (based on MPO's 2034 forecasts),
- forecasted socioeconomic characteristics (based on MPO's forecasts),
- forecasted highway congestion (estimated by model); and
- proposed level of transit service (user supplied input).

4.2 Alternatives Modeled

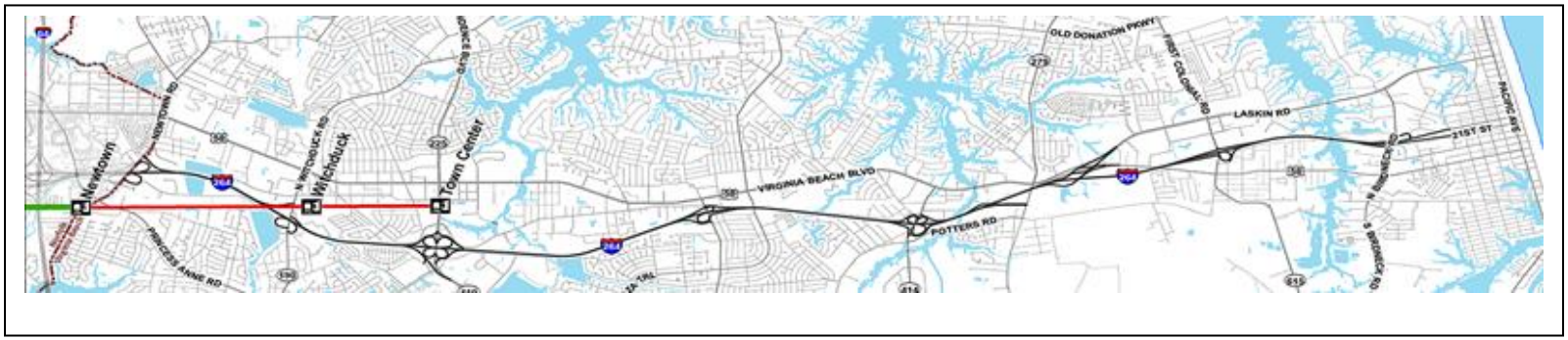
The LRT and BRT build alternatives and the No Build alternative were modeled using the calibrated HRT model. These alternatives include:

- Newtown Road to Town Center (LRT)
- Newtown Road to Rosemont (LRT)
- Newtown Road to Oceanfront via NSRR (LRT)
- Newtown Road to Oceanfront via Laskin Road (LRT)
- Newtown Road to Town Center (BRT)
- Newtown Road to Rosemont (BRT)
- Newtown Road to Oceanfront via NSRR (BRT)
- Newtown Road to Oceanfront via Laskin Road (BRT)
- No Build alternative

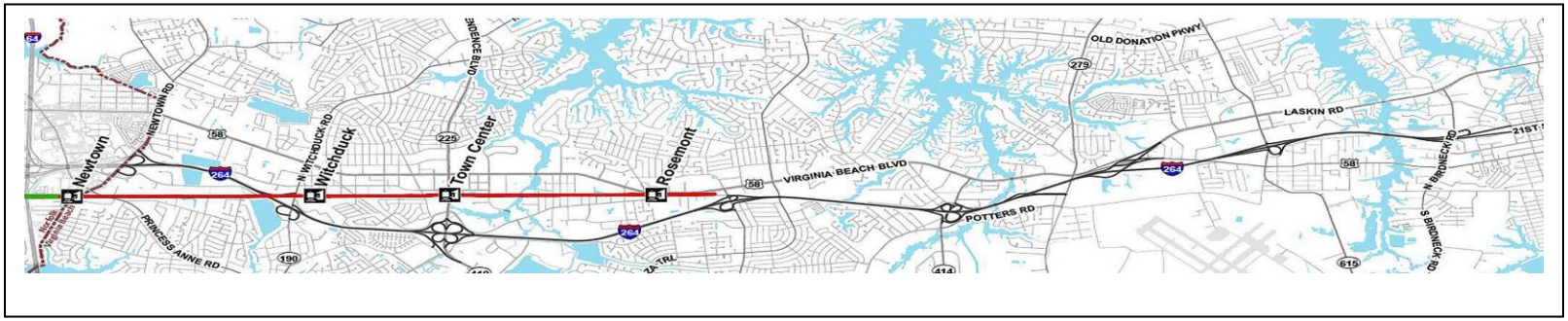
The alignments of the Build alternatives are shown in **Figure 2.**

Figure 2 | Alignments of Build Alternatives

Alternative 1A: Newtown Road to Town Center



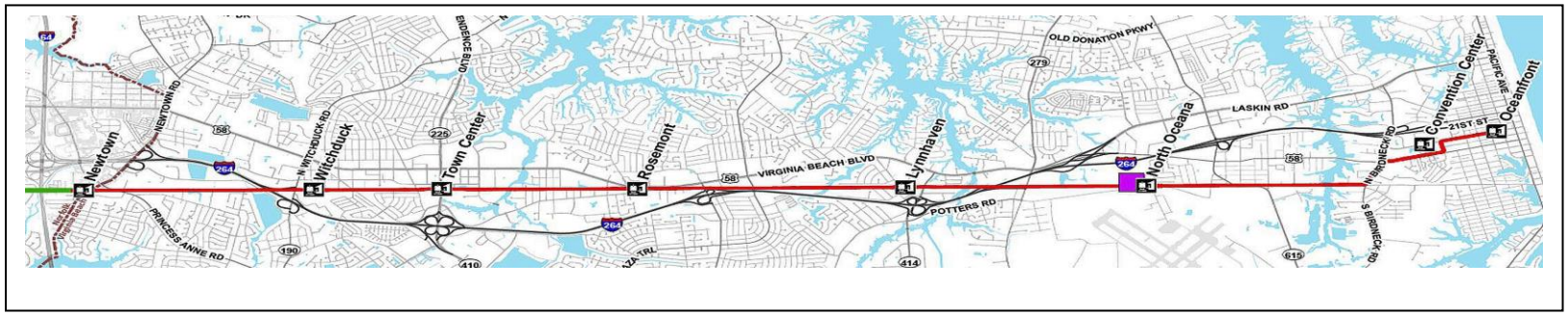
Alternative 1B: Newtown Road to Rosemont



Source: HDR, Inc.

Figure 2 (Continued) | Alignments of Build Alternatives

Alternative 2: Newtown Road to Oceanfront via NSRR



Alternative 3: Newtown Road to Oceanfront via Laskin Road

Source: HDR, Inc.

4.3 Ridership Results

Presented in **Table 1** is a summary of the 2034 projected passenger boardings for each transit alternative. It includes boardings at Virginia Beach stations as well as total boardings for the entire system (from the EVMC/Fort Norfolk Station at the western end of The Tide in Norfolk to the east end of the alignment in Virginia Beach). The LRT alternatives would be an extension of the existing Tide alignment and therefore provide a one-seat ride to all the locations in the Virginia Beach corridor. The BRT alternatives, on the other hand, use a different vehicle technology and therefore would involve a forced transfer for those passengers wanting to travel to Virginia Beach stations from The Tide. All BRT alternatives will start from the Newtown Road station, traveling east toward the oceanfront. The BRT stations would be located at the same locations as the LRT stations. The travel speeds on BRT alternatives were assumed to be about the same as light rail speeds. However, the BRT alternative was modeled as a bus mode. Therefore, some model parameters that capture the premium characteristics of the rail mode were not applied to the BRT mode.

Table 1 | 2034 Daily Ridership Projections for LRT and BRT Alternatives

	LRT Alternatives				BRT Alternatives			
	Alt. 1A	Alt. 1B	Alt. 2	Alt. 3	Alt. 1A	Alt. 1B	Alt. 2	Alt. 3
New Stations[1]	2,250	3,370	5,295	8,845	2,340	2,960	4,395	6,730
Total System (Virginia Beach and Norfolk)	**9,300**	**10,550**	**12,830**	**16,665**	**7,770**	**8,420**	**10,820**	**13,385**

[1] For LRT alternatives, "New Stations" refers only to stations in Virginia Beach.
For BRT alternatives, it refers to stations in Virginia Beach and BRT boardings at the Newtown Road Station in Norfolk.
The terms boardings, trips, and riders all refer to unlinked passenger trips.

Source: HDR, Inc.

As seen from **Table 1,** the LRT and BRT extensions to Town Center are projected to carry the least number of riders (9,300 and 6,330 per day in 2034), as expected, in comparison to the full extension to the Oceanfront. In general, the LRT alternatives are projected to carry approximately 20 to 25 percent more riders than the BRT alternatives. In Alternative 2, the LRT line which follows the NSRR alignment to the Oceanfront would carry about 12,830 riders a day in 2035. Of all the alternatives modeled, the LRT line in Alternative 3 (Hilltop alignment) is projected to carry the maximum number of riders, about 16,665 per day in 2034. This is mainly due to the fact that the Hilltop alignment goes through an area with a denser land use than the NSRR alignment. Among the BRT alternatives, again the Hilltop alignment produces the highest ridership.

Table 2 shows the year 2034 boardings at each station for the LRT and BRT alternatives. The Norfolk stations of The Tide are included. In general, the proposed stations with the largest ridership are in the western portion of the extension: Witchduck, Town Center, and Rosemont. For each alternative, the LRT ridership is greater than the corresponding BRT ridership at each station, except at Newtown Road due to transfers between The Tide and the BRT system.

Patrons reach the LRT or BRT stations via various modes of transportation, such as driving to a Park & Ride, walking, or transferring to or from a feeder bus that stops at the station. The ridership forecast model estimates the proportion of boardings that access the station by each mode. The model at this time does not have capacity constraints on the LRT or BRT cars or at the park and ride lots. The model assumes all unlimited capacity is available to accommodate the projected demand.

The modes of access for each station in the VBTES alternatives are shown in **Table 3** for all four alternatives using the LRT technology. The BRT alternatives would have approximately similar mode of access shares. As seen from the table, the highest walk access boardings are projected to occur at Rosemont Station, Hilltop East and Birdneck stations under the Hilltop alternative. The Convention Center station is projected to have a fairly high amount of park and ride activity. North Oceana station would have a significant transfer activity.

4.4 Ridership from Special Events

The travel demand model is designed to compute and project transit ridership on a typical weekday for the following trip purposes only: home based work trips, home based other trips and non-home based trips. It does not account for special event trips and tourist trips, which are potentially significant sources of ridership in the region. Shown in **Table 4** are some selected special event activities that take place in Norfolk and Virginia Beach. A different off-model procedure was established to compute those trips separately. The main data used in that procedure comes from a Cross-Visitation survey conducted in 2011-2012[11].

The Cross-Visitation survey data show there are 6.8 million day visitors and 5.9 million overnight visitors in the study area. The number of these visitors that arrive by auto versus air is also known from the survey. In order to compute the number of visitors that are most likely to use the rail transit, as assumption was made that 2 percent of the air visitors and 1 percent of auto visitors would use the rail mode. Based on these assumptions, we estimate there would be 221,000 annual rail trips made in summer and late summer months and 119,000 annual rail trips made during non-summer months. Presented in **Table 5** is a summary of the calculations.

[11] Cross Visitation Survey, 2011-2012, Prepared for Norfolk Tourism Research Foundation, by Continental Research Foundation.

Table 2 | 2034 Daily LRT and BRT Boardings by Station

	LRT Alternatives				BRT Alternatives			
Norfolk Stations (The Tide)	**Alternative 1A**	**Alternative 1B**	**Alternative 2**	**Alternative 3**	**Alternative 1A**	**Alternative 1B**	**Alternative 2**	**Alternative 3**
EVMC/Fort Norfolk	850	850	885	910	700	690	730	730
York Street/Freemason	350	350	355	360	300	290	300	290
Monticello	600	620	635	650	500	500	520	520
MacArthur Square	800	810	845	885	640	650	690	700
Civic Plaza	600	610	665	705	490	500	545	565
Harbor Park	450	440	440	450	350	350	360	360
NSU	500	530	560	590	450	430	460	470
Ballentine/Broad Creek	500	510	525	530	410	420	420	420
Ingleside Road	200	225	240	245	190	180	200	200
Military Highway	1,000	1,025	1,125	1,175	830	830	900	950
Newtown Road (LRT)	1,200	1,210	1,260	1,320	570	620	1,300	1,450
Newtown Road (BRT)	N/A	N/A	N/A	N/A	900	980	1,030	1,040
Virginia Beach Stations								
Witchduck	900	830	895	950	540	490	575	615
Town Center	1,350	1,550	1,725	1,890	900	910	1,100	1,220
Rosemont	N/A	990	940	1,050	N/A	580	600	680
Lynnhaven	N/A	N/A	570	360	N/A	N/A	365	230
North Oceana	N/A	N/A	200	N/A	N/A	N/A	120	N/A
Great Neck	N/A	N/A	N/A	895	N/A	N/A	N/A	575
Hilltop West	N/A	N/A	N/A	1,075	N/A	N/A	N/A	700
Hilltop East	N/A	N/A	N/A	450	N/A	N/A	N/A	300
Birdneck	N/A	N/A	N/A	920	N/A	N/A	N/A	600
Convention Center	N/A	N/A	210	225	N/A	N/A	130	120

Oceanfront	N/A	N/A	755	1,030	N/A	N/A	475	650
Total LRT Boardings	**9,300**	**10,550**	**12,830**	**16,665**	**5,430**	**5,460**	**6,425**	**6,655**
Total BRT Boardings	**0**	**0**	**0**	**0**	**2,340**	**2,960**	**4,395**	**6,730**
Total System Boardings	**9,300**	**10,550**	**12,830**	**16,665**	**7,770**	**8,420**	**10,820**	**13,385**

Source: HDR, Inc.

Table 3 | Mode of Access for Virginia Beach Stations

	Alternative 1A			Alternative 1B			Alternative 2			Alternative 3		
Stations	**Walk**	**P&R**	**Transfer**	**Walk**	**P&R**	**Transfer**	**Walk**	**P&R**	**Transfer**	**Walk**	**P&R**	**Transfer**
Witchduck	52%	27%	21%	53%	15%	32%	53%	14%	32%	53%	14%	33%
Town Center	62%	21%	17%	61%	11%	28%	61%	10%	29%	61%	9%	30%
Rosemont	--	--	--	68%	32%	0%	79%	21%	0%	82%	18%	0%
Lynnhaven	--	--	--	--	--	--	40%	32%	28%	55%	45%	0%
North Oceana	--	--	--	--	--	--	0%	26%	74%	--	--	--
Great Neck	--	--	--	--	--	--	--	--	--	44%	7%	49%
Hilltop West	--	--	--	--	--	--	--	--	--	67%	7%	27%
Hilltop East	--	--	--	--	--	--	--	--	--	88%	11%	2%
Birdneck	--	--	--	--	--	--	--	--	--	90%	10%	0%
Convention Center	--	--	--	--	--	--	34%	66%	0%	62%	38%	0%
Oceanfront	--	--	--	--	--	--	53%	1%	47%	54%	0%	46%

Source: HDR, Inc.

Table 4 | Selected Special Events in the Study Area

Special Events in Virginia Beach All events take place in the Oceanfront Resort Area	**Attendance**
Neptune Festival (Last weekend in September)	450,000
East Coast Surfing Championships (August)	235,000
Boardwalk Art Show (June)	150,000
Independence Day Fireworks (July)	100,000
North American Sand Soccer Championships (February-May)	90,000
American Music Festival (Labor Day Weekend)	85,000
Patriotic Festival (May/June)	55,000
Rock & Roll Half Marathon (Labor Day weekend)	35,000 runners and spectators
Shamrock Sportsfest Weekend (March)	28,000
Monsters at the Beach—Monster truck competition on the sand (May)	17,000
Special Events in Norfolk All events take place in Downtown Norfolk	**Attendance**
Harborfest (June)	250,000
Grand Illumination Parade (November)	80,000
Town Point Virginia Wine Festival (May and October)	25,000
Bayou Boogaloo & Cajun Food Festival (June)	20,000
Virginia Children's Festival (October)	15,000
Independence Day Fireworks (July)	12,000

Note: Approximately 175 events occur at the Virginia Beach Convention Center annually.
Source: HDR, Inc. and event organizers

Table 5 | Special Event and Tourist Trips

Arrivals by Air	Total Annual Number of Visitors	% Visitors by Air	Visitors by Air	Generated Trips	Transit Share	Transit Trips
Day visitors	6,800,000	0.34	2,312,000	4,624,000	0.02	92,480
Overnight visitors	5,900,000	0.34	2,006,000	4,012,000	0.02	80,240
Arrivals by Auto	**Total Annual Number of Visitors**	**% Visitors by Auto**	**Visitors by Auto**	**Generated Trips**	**Transit Share**	**Transit Trips**
Day visitors	6,800,000	0.66	4,488,000	8,976,000	0.01	89,760
Overnight visitors	5,900,000	0.66	3,894,000	7,788,000	0.01	77,880
					Total annual transit trips	**340,360**
					Summer and late summer transit trips (65%)	**221,000**
					Non-summer transit trips (35%)	**119,000**

Source: HDR, Inc.

Table 6 shows a summary of daily and annual ridership for all of the LRT and BRT alternatives. The weekday and weekend ridership together makes up more than 90 percent of the annual ridership. Special events and tourist trips are projected to range from 3 to 9 percent, depending on the alternative. In general, the LRT alternatives are likely to generate anywhere from 16 to 24 percent higher ridership than the BRT alternatives.

Table 6 | Summary of Daily and Annual Ridership for LRT and BRT Alternatives

	Light Rail Transit				Bus Rapid Transit			
	Alternative 1A	Alternative 1B	Alternative 2	Alternative 3	Alternative 1A	Alternative 1B	Alternative 2	Alternative 3
Weekday	9,300	10,550	12,830	16,665	7,770	8,420	10,820	13,385
Annual weekdays	2,418,000	2,743,000	3,335,800	4,332,900	2,020,200	2,189,200	2,813,200	3,480,100
Weekend day	3,999	4,537	5,517	7,166	3,341	3,621	4,653	5,756
Annual weekend days	419,895	476,333	579,275	752,425	350,816	380,163	488,523	604,333
Total annual (weekday and weekend)	2,837,895	3,219,333	3,915,075	5,085,325	2,371,016	2,569,363	3,301,723	4,084,433
Annual Special events/tourist trips	102,000	102,000	340,000	340,000	102,000	102,000	340,000	340,000
Total (Rounded)	**2,939,900**	**3,321,000**	**4,255,000**	**5,425,000**	**2,473,000**	**2,671,350**	**3,641,700**	**4,424,450**

Source: HDR, Inc.

Appendix K-1

Technical Memorandum Dated : 11/08/2011

To: **Ray Amoruso, Karen Waterman, Hampton Roads Transit**

From: **Vijay Mahal and Nick Karcz, HDR Inc**

Copy: **Eric Nelson, Pete Mazurek HDR Inc**

Date: **11/08/2011**

Subject: **VBTES WA8: Review of Opening Year Forecasts for The TIDE Light Rail Line**

Introduction

This technical memorandum documents the results of the pre-opening and post opening year ridership forecasts for The Tide light rail line (The Tide or Tide). The purpose of these model runs is to compare the previously modeled opening year forecast (completed in 2006-2007), which uses older socioeconomic data and highway/transit networks, with updated datasets to see how well the forecasts reflect the existing conditions. This memorandum describes the development of the 2011 base transportation network, the modeled scenarios, and the model results.

The travel demand forecasting model for the Hampton Roads Region is primarily owned and maintained by the Virginia Department of Transportation (VDOT). VDOT, through its consultants, developed the base networks, coding, and other necessary seed files necessary for highway project prioritization and air quality conformity. The Hampton Roads Transportation Planning Organization (HRTPO), the local MPO, developed the socio-economic inputs (in coordination with the local cities), and other local coordination and validation of the model. Hampton Roads Transit (HRT) provided VDOT and HRTPO with transit routes and schedules sufficient to develop the transit component of the model.

Base Network Development

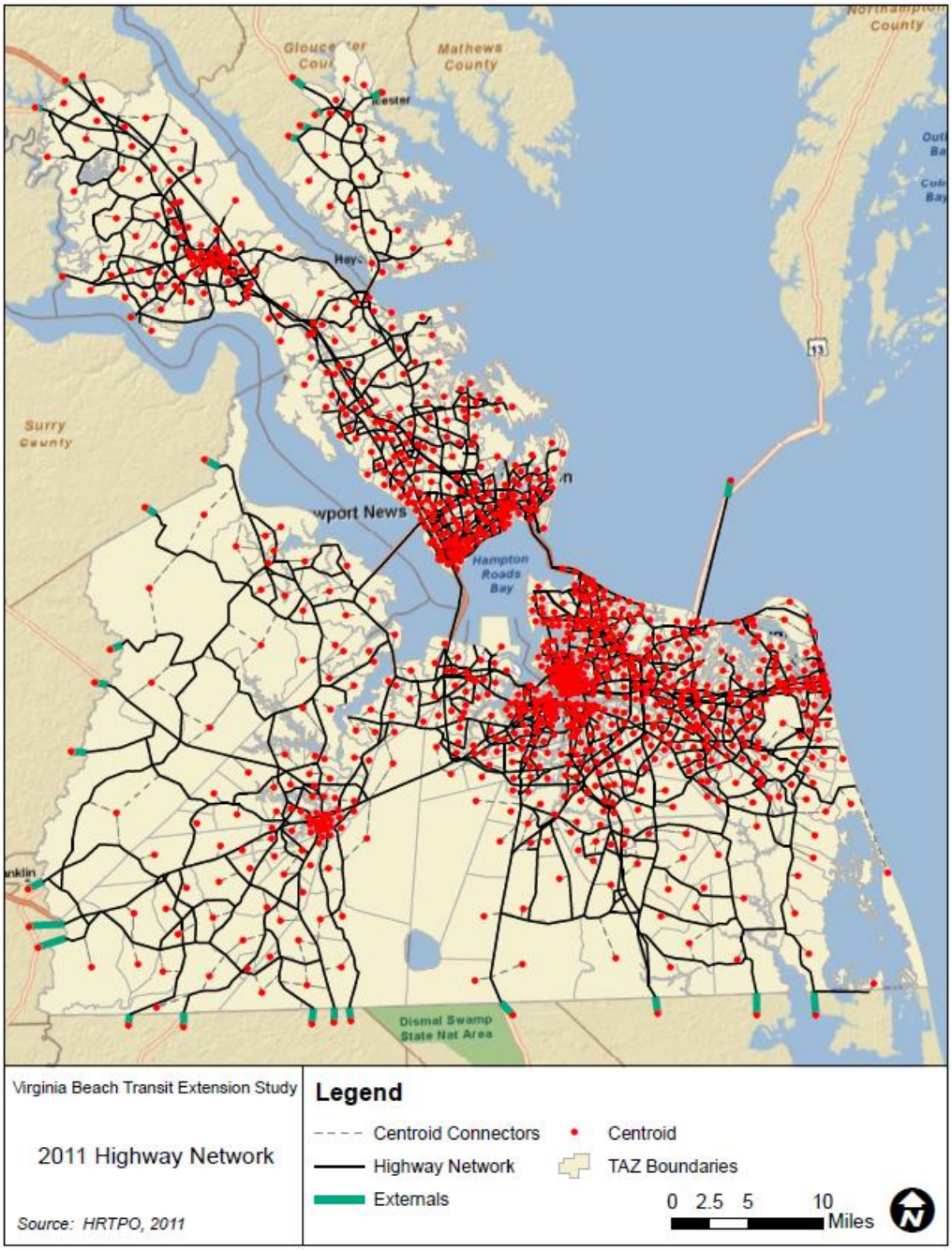
A 2011 model was not available from the Hampton Roads Transportation Planning Organization (HRTPO); therefore, a 2011 base network needed to be developed using available datasets. This section summarizes the development of the highway and transit networks, as well as the 2011 socioeconomic data.

2011 Highway Network

The 2010 highway network was obtained from the HRTPO. The highway network was reviewed and spot checked for accuracy. No major highway links were modified, added, or removed in the 2010 network in order to reflect 2011 conditions. Where necessary, minor modifications

were made to highway links to allow rerouting of some bus routes to represent current operation. **Figure 1** identifies the 2011 highway network as well as the centroids, centroid connectors, and external links.

Figure 1: 2011 Highway Network



2011 Transit Network

The most up-to-date current transit network was not available from the HRTPO. It was determined that the 2030 No Build transit network (used in the Virginia Beach Transit Extension

Study and reflects the Pre-LRT transit network) could be modified within the Norfolk/Virginia Beach area to reflect the June 2011 conditions. Fares and access links on all modes were checked for accuracy. This section documents the routes and headways that were assumed.

Local Service

Utilizing the schedules on the Hampton Roads Transit (HRT) website, local routes within the cities of Norfolk, Virginia Beach, Chesapeake, and Portsmouth were reviewed and modified to reflect the June 2011 (Pre-LRT opening) conditions. Several modifications were made to the modeled bus routes to ensure all the coded routes represented the 2011 transit service in terms of routing, stops, intermodal connectivity and headways. Other local HRT routes within the cities of Hampton, Newport News, and Suffolk were not modified as these routes do not directly affect the study area. **Table 1** identifies the local routes within the cities of Norfolk, Virginia Beach, Chesapeake, and Portsmouth that were reviewed. **Table 2** identifies the local routes with the cities of Hampton, Newport News, and Suffolk. **Figure 2** identifies the local routes within in the HRT service area.

Table 1: HRT Local Routes
Norfolk, Virginia Beach, Chesapeake, Portsmouth

Route	Headways		Route	Headways	
	Peak	Off-Peak		Peak	Off-Peak
HRT1A	60	60	HRT20B	30	30
HRT1B	60	60	HRT23	30	30
HRT2	30	30	HRT25A	60	60
HRT3A	60	60	HRT26A	60	60
HRT3B	20	60	HRT26B	60	60
HRT4	60	60	HRT27	60	60
HRT5	60	60	HRT29	60	60
HRT6A	60	60	HRT33A	60	60
HRT6B	60	60	HRT33B	60	60
HRT8	30	30	HRT36	60	60
HRT9	30	30	HRT37	60	60
HRT11	30	30	HRT41	60	60
HRT12	60	60	HRT43	60	60
HRT13A	60	60	HRT44	60	60
HRT13B	60	60	HRT45	30	30
HRT14	60	60	HRT47A	60	60
HRT15A	60	60	HRT47B	60	60
HRT15B	60	60	HRT50	60	60
HRT15C	30	0	HRT57	60	60
HRT16	30	30	HRT58	60	60
HRT17A	30	0	VAB30	15	15
HRT17B	30	15	VAB31	20	20
HRT18	60	60	VAB32	60	60
HRT20A	30	30	VAB34	15	15

Source: HDR, 2011.

Table 2: HRT Local Routes
Hampton, Newport News, Suffolk

Route	Headways		Route	Headways	
	Peak	Off-Peak		Peak	Off-Peak
PEN101	15	30	PEN201	15	15
PEN102	60	60	PEN202	30	30
PEN103	30	30	PEN203	15	15
PEN104	30	30	PEN204	30	30
PEN105	60	60	PEN302	90	0
PEN106	30	30	PEN303	90	0
PEN107	30	30	PEN304	90	0
PEN109	60	60	PEN305	90	0
PEN110	60	60	SFLK1	60	60
PEN111	60	60	SFLK2	60	60
PEN112	30	30	SFLK3	60	60
PEN114	30	30	SFLK4	60	60
PEN115	60	60	WATBLU	60	60
PEN115ST	60	60	WATPUR	60	60
PEN116	30	60	WATORG	60	60
PEN117	30	30	WATGRN	60	60
PEN118	60	60	WATRED	60	60
PEN120	60	60	WATTAN	60	60
PEN122	30	30	WATGRY	60	60
PEN123	30	60	WATHIGH	30	30
PEN124	60	60	WATMDCTR	30	30
PEN131	30	60	GLSHUT	20	0

Source: HDR, 2011.

Express Service

There are 13 express routes in the model and no express routes were modified. **Table 3** and **Figure 3** identifies the express service in the HRT service.

Table 3: Express Service

Route	Headways	
	Peak	Off-Peak
HRTX61A	60	60
HRTX61B	60	60
HRTX61C	60	60
HRTX64	45	0
HRX121	60	0
NORE3PK	36	0
NORE3REV	90	0
NSN5	60	0
NSN6	60	0
HRTX19	15	0
HRTX22	15	0
HRT28	30	30
HRTX62	15	30

Source: HDR, 2011.

Figure 2: HRT Local Service

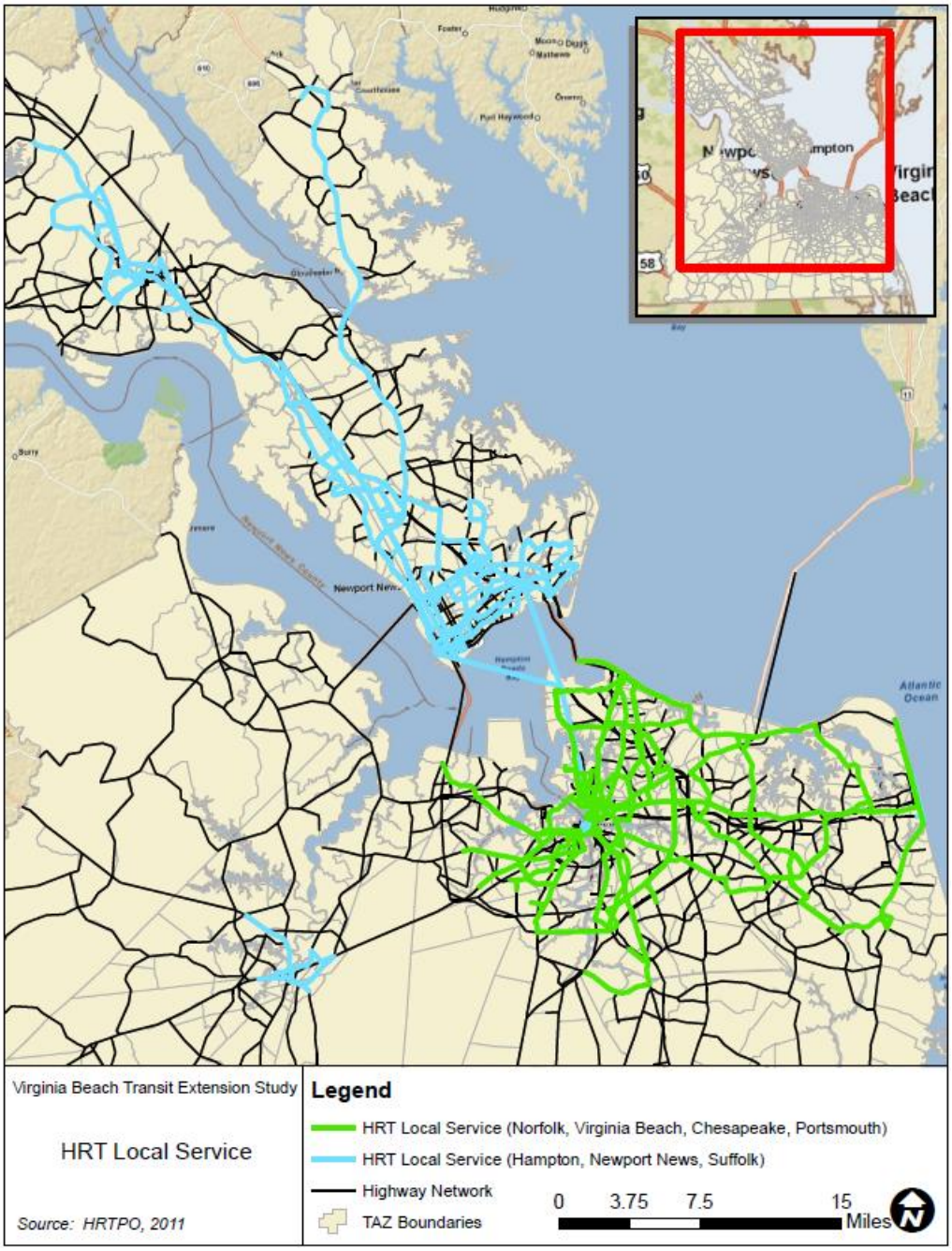
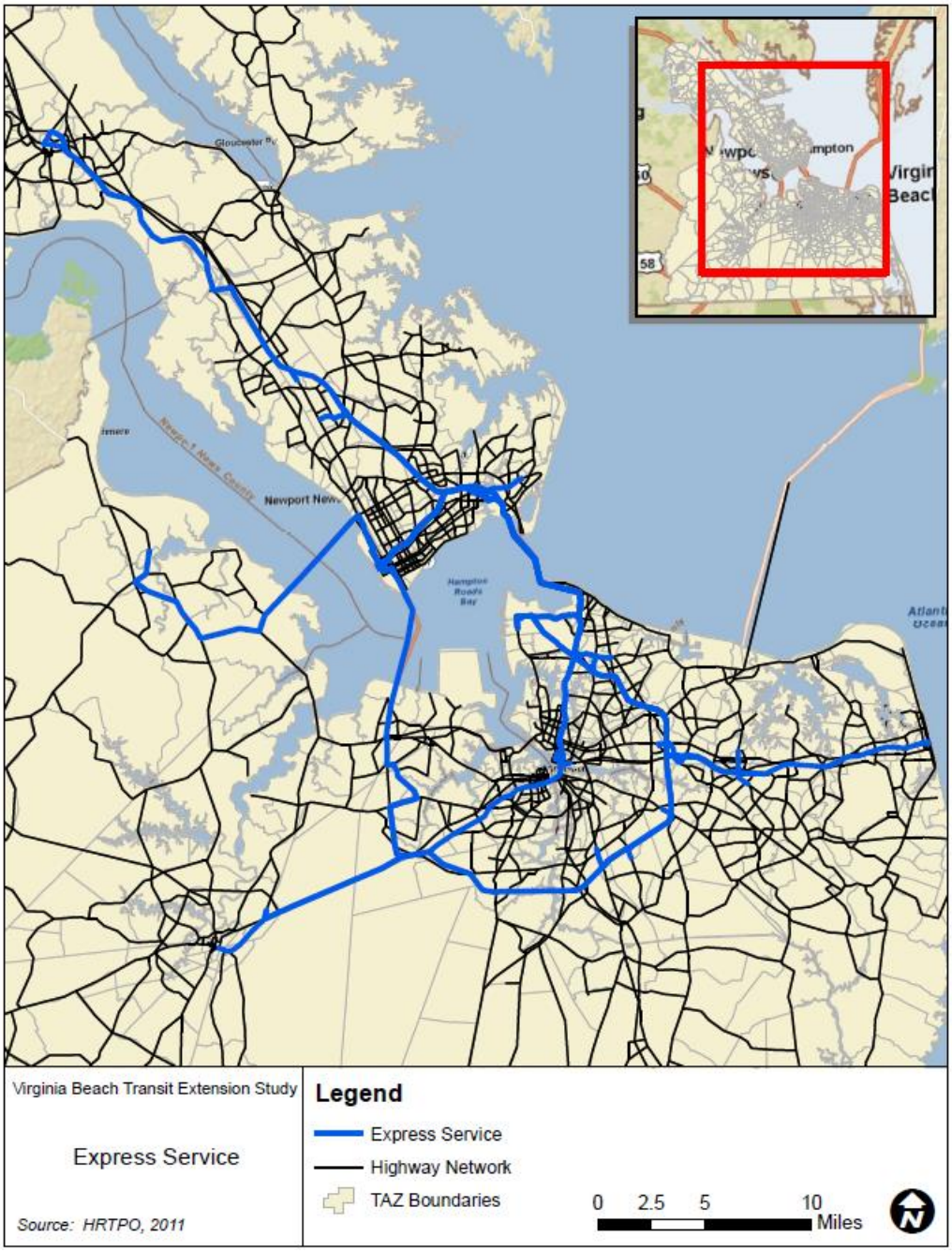


Figure 3: Express Service



Premium Service

The Tide is the only premium service in the model. This route operates between EVMC and Newtown Road with 10-minute peak and 15-minute off-peak service. The alignment, station locations and station access for The Tide was adjusted to ensure consistency with current operation. Local bus route connections were verified by station to ensure intermodal connectivity. The 11 stations, including four with parking facilities are shown below:

- EVMC;
- York Street/Freemason;
- Monticello;
- MacArthur Square;
- Civic Plaza;
- Harbor Park (Parking);
- Norfolk State;
- Ballentine/Broad Creek (Parking);
- Ingleside Road;
- Military Hwy (Parking); and
- Newtown Road (Parking).

The station to station travel times on The Tide was adjusted to be consistent with the travel times posted on the HRT website and average actual operations. **Table 4** shows the station to station travel times for The Tide and **Figure 4** depicts The Tide alignment and associated stations coded in the model.

Table 4: The Tide Station to Station Travel Times

From Station	To Station	Time (min)
EVMC	York Street/Freemason	2.50
York Street/Freemason	Monticello	3.00
Monticello	MacArthur Square	3.00
MacArthur Square	Civic Plaza	3.00
Civic Plaza	Harbor Park	2.00
Harbor Park	Norfolk State	3.00
Norfolk State	Ballentine/Broad Creek	2.00
Ballentine/Broad Creek	Ingleside Road	2.00
Ingleside Road	Military Hwy	3.00
Military Hwy	Newtown Road	3.00
Total		**26.50**

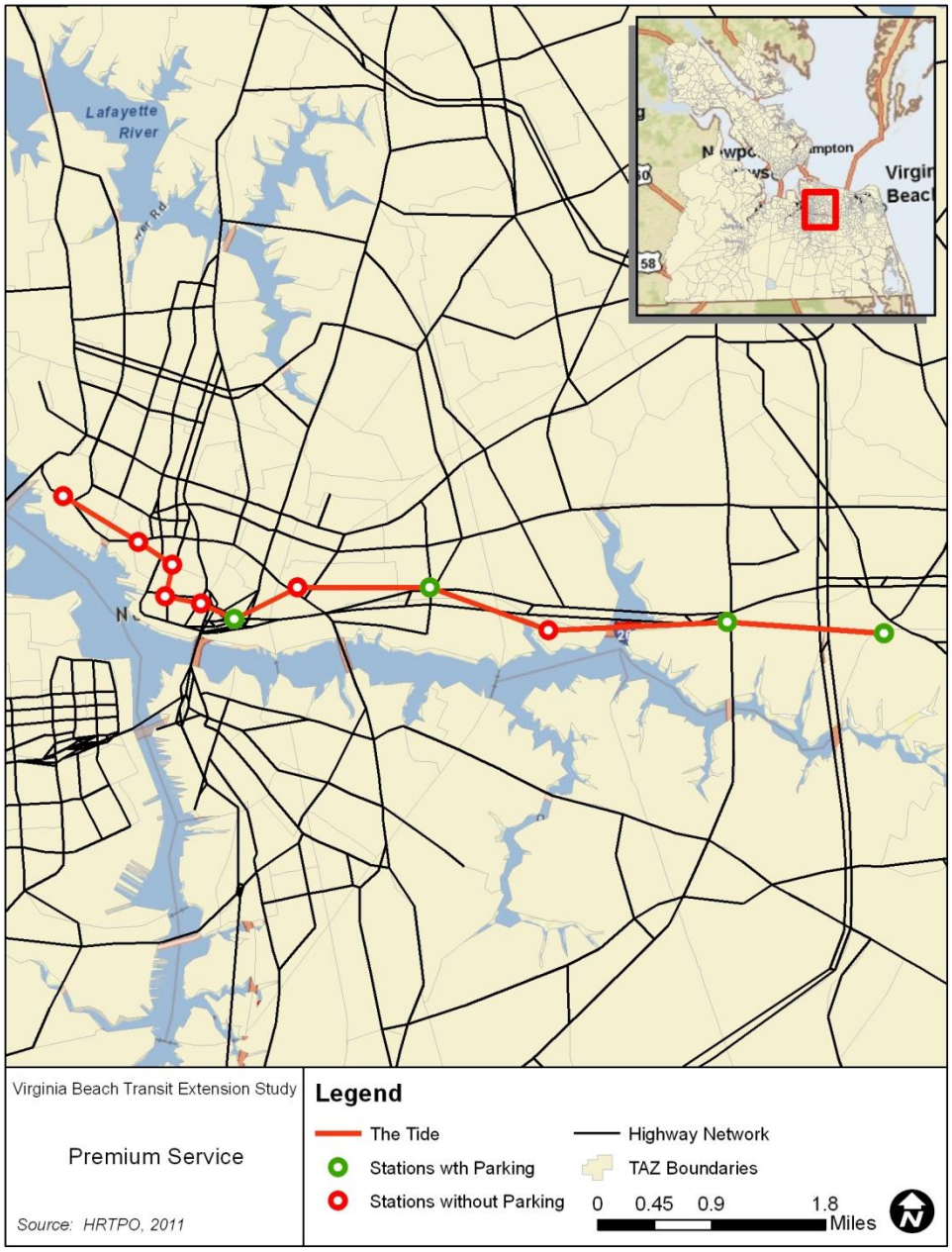
Source: HRT website, September 2011.

Intermodal Connectivity

The bus network in the model provides transfer opportunities at the following LRT stations:

EVMC: Routes 2, 16, 17, 23, 44
Civic Plaza Station: Routes 6, 8, 45, 960, 961
NSU Station: Routes 9, 13, 18
Ballentine /Broad Creek: Route 18
Military Highway Station: Routes 15, 23, 967
Newton Road Station: Routes 20, 25, 27

Figure 4: Premium Service



Park-and-Ride Facilities

There are three types of park-and-ride facilities in the HRT service area: Express, Premium, and Fringe. All of these facilities are located in the Southside service area.

The model contains five express parking facilities. They are:

- Silver Leaf;
- Greenbrier Mall;

- Indian River;
- Strawbridge; and
- Sam's Club.

The model contains four premium parking facilities that serve The Tide, all of which are in Norfolk. They are:

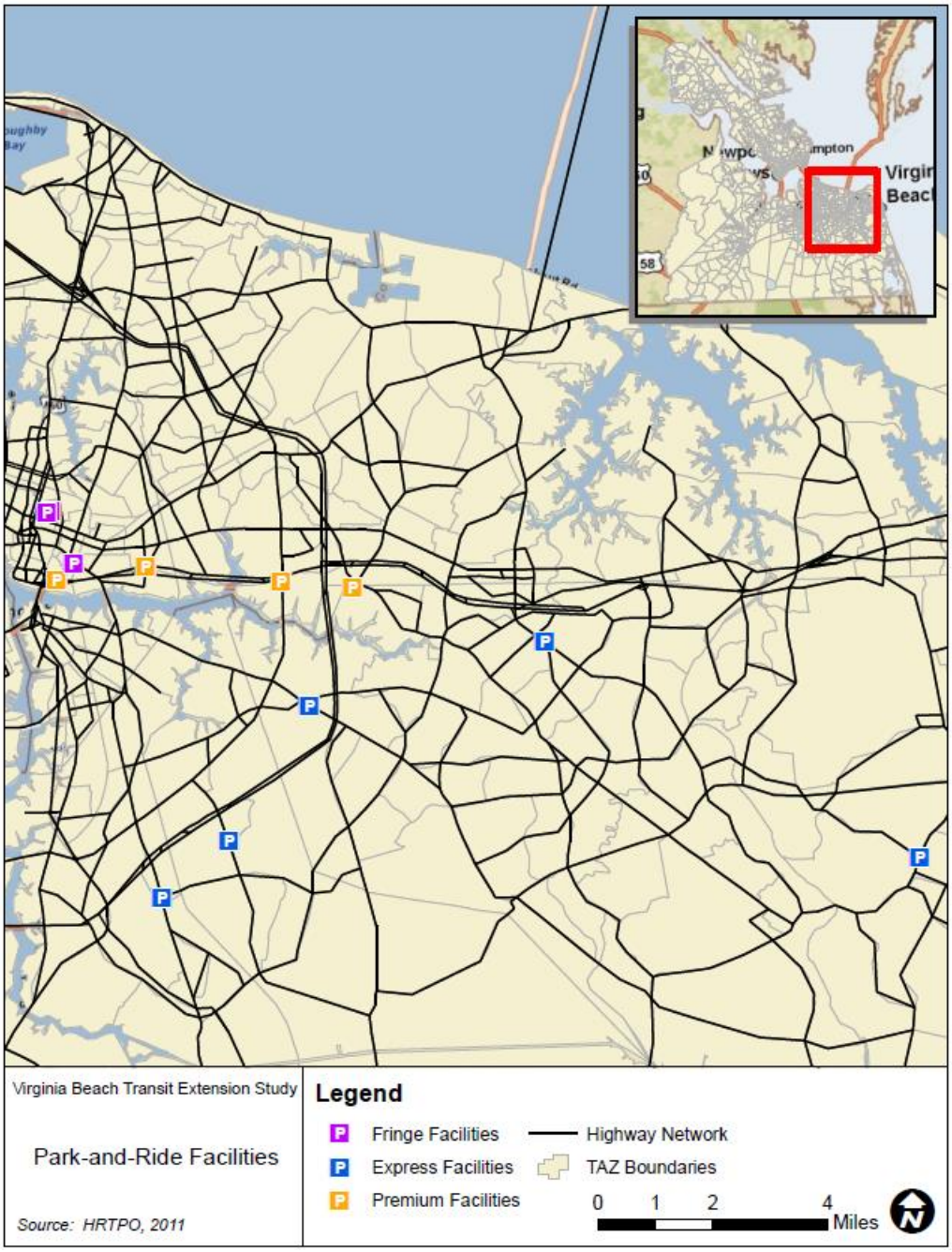
- Harbor Park;
- Ballentine/Broad Creek;
- Military Highway; and
- Newtown Road.

The model contains three fringe parking facilities that service downtown Norfolk. They are:

- Harbor Park;
- Harrison Opera House; and
- Lot 39.

Figure 5 identifies the express, premium, and fringe parking facilities.

Figure 5: Parking Facilities



2009 Socioeconomic Data

The 2011 Socio-economic data set was not available from HRTPO. Therefore, their 2009 Socio-economic data was obtained and compared against the 2010 Census data. This comparison was made just for the City of Norfolk as the entire rail alignment is contained within the city. For comparing the employment numbers, we used the 2010 data from Longitudinal Employment Household Dynamics (LEHD) data base. The LEHD data base uses information from the Census and the department of labor. **Table 6** summarizes the comparison of the 2009

and 2010 population and employment data. As seen, the 2010 Census population is very close to HRTPO's 2009 estimates. On the employment side, the actual 2010 employment is about 10 % lower than the 2009 employment estimate for the whole city. When comparing the downtown employment, the actual 2010 employment is about 4 percent lower than the HRTPO's 2009 estimate. Based on this comparison, it was determined that for this analysis, the 2009 socioeconomic data would be sufficient to run the 2011 model.

Table 6: Population and Employment Data Comparison for City of Norfolk

	2009 HRTPO (estimated)	2010 Census / 2010 LEHD (Actual)	Difference
Population (City of Norfolk)	237,625	242,800	Census is 2% higher
Employment (City of Norfolk)	150,380	135,050	LEHD is 10% lower
Downtown Employment* (*covers CBD area bounded by Park Ave. on the east side and 39th St on the north side.)	62,600	59,000	LEHD is 4 % lower

Source: HRTPO, 2011; US Census Bureau, 2010.

Modeled Scenarios

Two scenarios were modeled for this exercise:

- Scenario 1 – Pre-Opening: This scenario represents the condition just before the Tide rail line went into service. It has all the bus service changes HRT implemented as part of the rail line. Some of these changes were introduced in May 2011 and the rest in August 2011 as shown in **Table 7.**
- Scenario 2 – Post Opening: This scenario utilizes the Pre-Opening base network as defined above and contains The Tide rail line. All the bus route changes as of August 2011 are included in this scenario.

Table 7: Bus Service Changes associated with The Tide rail line

Type of Modification	May 22 Changes	August 7 Changes
Route Change	3, 36, 44C, 57	2, 4, 6, 8, 9, 13, 14, 15, 16, 17, 18, 20, 23, 25, 27, 44, 45, 960, 961, 967
Service Enhancement	104, 114	27
Service Reduction	37, 960, 962, 967,961	13
Route Interline	6, 14	N/A
Route Discontinued	963	310
New Route	34	N/A

Source: HDR Engg

Model Results

Table 8 provides a summary of the assumptions and model results for the pre-opening and post opening forecasts. In addition, the earlier forecasts conducted by AECOM in March 2007 are also provided in the same table for comparison purposes.

As seen from the table, the model results show that there are approximately 30,100 boardings (unlinked transit trips) in the transit system prior to the opening of The Tide, and an additional 1,800 boardings are added when The Tide is in operation. According to the HRT, the average daily ridership numbers for May 2010 to April 2011 is approximately 52,700 boardings, which is more than 75 percent higher than the modeled results. In other words, the model is severely underestimating transit demand in the entire system.

For the TIDE line, the model results indicate the opening year ridership is about 2,870 daily boardings which is very similar to the forecasts made by AECOM in March 6, 2007 (2,900 boardings). However, observed ridership on The TIDE is averaging approximately 5,260 riders per day (through Sept 30, 2011).

Table 8: Model Results Summary

	AECOM's Opening Year Forecast (March 2007)	HDR's Pre-Opening Forecast (September 2011)	HDR's Post Opening Forecast (September 2011)
Assumptions			
Socio-Economic Data	Based on 2011 projections by HRTPO	Based on HRTPO's 2009 estimates which are fairly close to 2010 Census data	Based on HRTPO's 2009 estimates which are fairly close to 2010 Census data
Highway Network	2000 network updated to 2011	2010 network from HRTPO	2010 network from HRTPO
Transit Network	2011 transit network provided by HRTPO	2011 network updated by HDR to current conditions.	2011 network updated by HDR to current conditions.
LRT Headways (Peak/Off-Peak)	7.5/10	not applicable	10/15
LRT Stations	11 stations	not applicable	11 stations
LRT Travel Time	25.5 minutes one way	not applicable	26.5 minutes one way
LRT Fares	$1.50	not applicable	$1.50
Shadow Prices for Downtown	No	No	No
Shadow Prices for Fringe Lots	Default value: 2 minutes	Default value: 2 minutes	Default value: 2 minutes
Stations with PNR Access	2	not applicable	4
Rte 17 S (NET) headway	7.5	15	15
Model Results			
Daily Ridership on The Tide	**2,900**	**not applicable**	**2,870**
Total Linked Transit Trips	**29,471**	**24,591**	**26,200**
Total Walk to Local Transit	not available	23,820	22,902
Total Walk to Premium Transit	not available	0	1,319
Total Drive to Local Transit	not available	181	180
Total Drive to Premium Transit	not available	0	892
Total Fringe-Parking to Transit	not available	591	907
Total Person Trips	**not available**	**6,397,702**	**6,397,683**
Total SOV Person Trips	not available	3,977,891	3,976,643
Total HOV Person Trips	not available	2,392,445	2,392,164
Total Fringe-Parking to Walk	not available	2,084	1,979
Total Fringe-Parking to Shuttle	not available	727	697
Total Mode Split (Percent)	**not available**	**0.38%**	**0.41%**
Unlinked Transit Trips (Systemwide)	not available	30,168	31,900

Source: HDR Engineering, 2011.

To determine why the model is consistently[12] underestimating the system wide transit demand as well as The Tide ridership, HDR conducted further investigations on the underlying assumptions embedded in the transit component of the model. The major findings are:

- In its current form, there are several restrictions placed on travel which completely disallow particular markets. It is possible these were put in place at the time the model was calibrated because comprehensive data were not then available to determine if such markets really existed. With a renewed emphasis on travel pattern data collection in recent years, the revisiting of these restrictions in the model is warranted. Restrictions include:
    - Transfers from rail to bus for those who use the park and ride mode to access the rail line are prohibited in the current model.
    - For Home Based Other trips, the current model does not allow park and ride mode to access rail.
    - Park and Ride trips to rail are allowed for CBD destinations only in the current model.
- The current model may be in need of proper calibration. When compared to 2011 observed ridership, the current model is underestimating transit ridership on virtually every existing bus route. In some cases, the underestimation is quite severe, as much as 70 percent. It is recommended that some additional diagnostic tests on the original calibration model run as well as the opening year model run performed by AECOM be conducted to confirm if a major recalibration of the transit assignment module is warranted.
- The values on downtown and fringe parking lot shadow prices need to be readjusted based on the existing parking utilization and constraints.

HDR believes implementing the above-mentioned technical suggestions would improve the overall forecasting ability of the HRTPO/VDOT model. As more ridership data become available for The Tide, HDR recommends revamping the access assumptions and path building parameters for the rail mode using observed data and recalibrating the rail component to actual ridership as part of the Virginia Beach Transit Extension Study.

[12]Norfolk LRT Project, EIS, Patronage Forecasting Report, prepared by AECOM, January 24, 2003,
Norfolk LRT Project, FEIS, Patronage Forecasting Report, prepared by AECOM, July 2005,
Norfolk LRT Project, Final Design, Patronage Forecasting Report, prepared by AECOM, March 6, 2007,
Norfolk LRT Project, Documentation of Conditions Before Project Implementation Report, AECOM, June 2008

Appendix K-2

Technical Memorandum dated 12/19/2011

To: **Ray Amoruso, Karen Waterman, Hampton Roads Transit**

From: **Vijay Mahal and Nick Karcz, Mike Rose HDR Inc**

Copy: **Eric Nelson, Pete Mazurek HDR Inc**

Date: **12/19/2011**

Subject: **VBTES WA #9: Review of the Calibration Year and Opening Year model runs**

Introduction/Background

In August 2011, at the request of HRT, HDR re-estimated the opening year ridership forecasts for The TIDE line using HRT's travel demand model with the most recently available network and demographic inputs. The results of that analysis were documented in an earlier technical memorandum (under WA #8); they indicated the current travel forecasting tools used by HRT have significant issues with underestimating the ridership on not only the rail mode but also on all existing regional transit services. In a recent meeting with the FTA, HRT presented their work plan to perform a major revision of the model to address this "underestimation" problem. FTA staff however, suggested that HRT conduct a series of diagnostic tests first before embarking on a major recalibration effort. Although the need to enhance the model (and take advantage of recent and future on-board survey data) is not in question, the results of the diagnostic tests would help guide the specific technical approach to enhancing and re-calibrating the forecasting tools. This memorandum summarizes the results of this diagnostic analysis.

Major Findings

- The total number of unlinked transit trips (system-wide transit boardings) in AECOM's calibration year model run is 35,800 which are much lower than the 58,000 boardings reported by HRT to FTA in 2003. This underestimation of transit demand in the calibration year is propagated to all the subsequent forecast year model runs. The National Transit database (NTD) indicates the actual transit boardings in HRT's service area ranged between 58,000 and 62,000 during the period 2000 to 2003.
- The total number of linked transit trips in AECOM's calibration run is 33,400. It is not clear where this target number was derived from. While the population and employment data used in AECOM's opening year run are 8.7 percent and 13 percent more than the Calibration year, the number of linked transit trips in the Opening year is about 8 percent lower than the Calibration year.
- Regarding the total person trips and transit person trips, there are some moderate differences among the model runs in terms of their magnitude and distribution.

However, those differences did not contribute to the overall underestimation of the transit demand in the region.

- Also, it is not clear why the complex trips in AECOM's Opening year run were not considered in Mode Choice.
- All three model runs (Calibration, AECOM's Opening Year, and HDR's Opening Year) significantly underestimate the Express bus ridership.
- In terms of transit and highway travel times, there are minor differences across the three model runs. Again, those differences do not explain the overall underestimation of the transit demand.

Methodology

As per FTA's suggestion, our overall approach consisted of comparing key model inputs and outputs at a district level for the calibration year model run as well as the opening year forecast runs and investigate whether any major anomalies related to network or input errors exist among different model runs. The keys inputs and outputs that were analyzed include:

- Socioeconomic (zonal) data
- Person trip tables (zone-to-zone and district-to-district)
- Transit trip tables (zone-to-zone and district-to-district)
- Revenue miles (transit network level of service), Transit and highway travel times (zone-to-zone)

Model Runs

For this analysis, inputs and outputs from three model runs were compared: Calibration Year run (as developed by AECOM), Opening Year run obtained from AECOM, and HDR's Opening Year run. The Calibration model was the most recent base year validation run (as documented in the model validation report for the TIDE FEIS and Final Design phases). The Opening Year model was the original TIDE opening year forecast (for year 2011 conducted by AECOM in 2006). HDR's run of the Opening Year was substantially the same as AECOM's Opening Year run, with the exception of some updates to the transit network (to account for changes implemented since 2006) and updated socioeconomic data (more recent information from the MPO). **Table 1** provides a brief summary of the model inputs for the three models. It is important to note that for the Calibration Model, only the routes that were used for calibrating the model, were included in the transit network.

Table 1: Model Input Summary

Model	Year Model Was Run	Socioeconomic Data Used	Network Used	
			Highway	Transit
Calibration Run (AECOM)	2004?	2000	2000	2000
Opening Year Run (AECOM)	2006	2011	2011 as seen in 2006	2011 as seen in 2006
HDR Opening Year	2011	2009	2011 as presently implemented	2011 as presently implemented

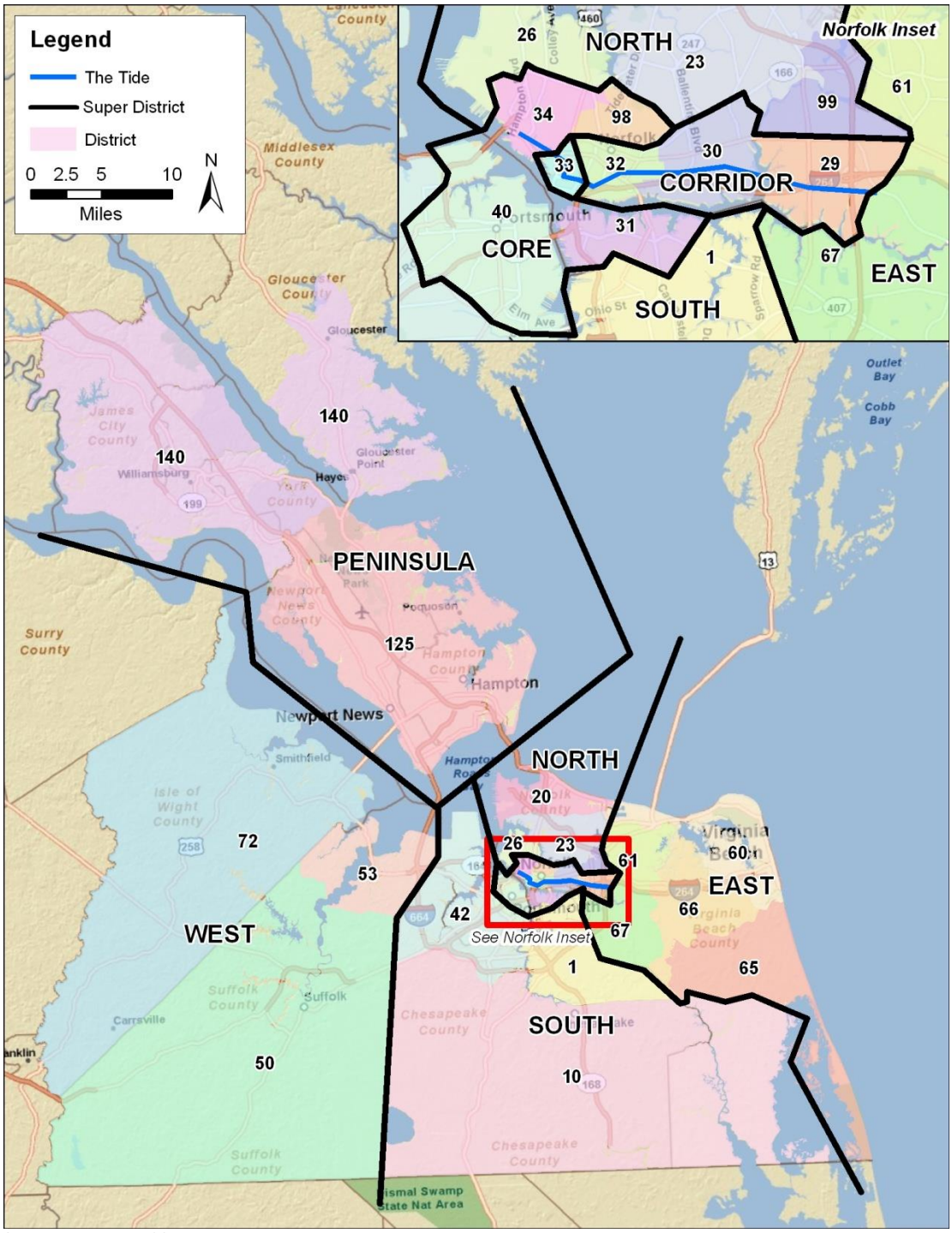
Source: HDR, Inc

District System Definition

The first step in this process was to develop a convenient district system that would make this comparative analysis easy and simple. **Figure 1** shows the district system that was developed for this analysis. As the figure shows, the district system is further organized into the following eight super districts:

- CBD – District 33
- CORE – Districts 31, 34, 40, 98
- CORRIDOR – Districts 29, 30, 32
- EAST – Districts 60, 61, 65, 66, 67
- NORTH – Districts 20, 23, 26, 99
- SOUTH – Districts 1, 10, 42
- WEST – Districts 50, 53, 72
- PENINSULA – Districts 125, 140

Figure 1: District and Super District System



Source: HDR Inc, 2011.

Analysis of Model Inputs and Outputs

Once the districts system was defined, the following inputs and outputs were compared for all the three model runs discussed earlier:

- Socioeconomic data;
- Person trips;
- Transit trips;
- Revenue miles; and
- Travel times for drive alone and transit.

Socioeconomic Data Review

Table 2 identifies the population and employment data for each of the model runs. A review of the population and employment data concludes the following:

- The 2011 overall population and employment data used in HDR's Opening year model run are about 3 to 4 percent lower than the AECOM's Opening Year model run.
- The CBD employment in AECOM's Opening Year model run is higher than the employment used in the other two model runs.
- Population in the study Corridor is comparable across all model runs, but employment is less in the HDR's Opening year model run than the other two models.
- In general, the magnitude of population and employment inputs used in all three model runs are comparable.
- **In general, the review of the socio-economic inputs did not reveal any major anomalies or inconsistencies across model runs.**.

Table 2: Socioeconomic Data

Districts	Population			Employment		
	Calibration	Opening Year	HDR Opening	Calibration	Opening Year	HDR Opening
CBD						
33	2,479	2,390	3,168	24,364	33,831	24,449
CBD Total	*2,479*	*2,390*	*3,168*	*24,364*	*33,831*	*24,449*
Core						
31	7,454	7,880	7,373	7,878	8,144	7,485
34	10,940	10,418	11,615	23,909	20,546	25,022
40	22,170	24,876	21,835	30,562	35,104	30,927
98	7,209	6,434	7,547	552	1,309	2,442
Core Total	*47,773*	*49,608*	*48,370*	*62,901*	*65,103*	*65,876*
Corridor						
29	7,899	8,275	8,433	18,531	27,387	15,161
30	10,275	10,500	10,105	11,628	8,949	11,754
32	8,188	8,061	8,553	10,592	7,986	9,011
Corridor Total	*26,362*	*26,836*	*27,091*	*40,751*	*44,322*	*35,926*
East						
60	89,469	101,647	88,100	55,221	69,325	57,500
61	60,236	65,630	59,568	45,936	45,741	42,595
65	58,792	66,816	64,206	23,123	23,025	30,250
66	111,786	127,708	115,569	81,196	84,882	85,628
67	100,148	104,008	101,947	35,314	35,863	42,535
East Total	*420,431*	*465,809*	*429,390*	*240,790*	*258,836*	*258,508*
North						
20	76,472	74,630	77,642	81,066	78,775	80,489
23	76,109	70,924	76,020	31,706	30,340	34,328
26	21,750	22,636	21,506	8,078	8,598	8,245
99	5,628	4,455	5,660	9,927	9,833	8,279
North Total	*179,959*	*172,645*	*180,828*	*130,777*	*127,546*	*131,341*
Peninsula						
125	384,787	400,846	393,409	216,290	241,986	223,561
140	93,272	117,463	113,599	70,803	89,504	91,401
Peninsula Total	*478,059*	*518,309*	*507,008*	*287,093*	*331,490*	*314,962*
South						
1	83,129	97,032	92,941	65,670	65,237	80,685
10	71,968	87,053	79,452	17,374	43,145	23,008
42	127,308	131,026	128,903	44,769	59,087	51,232
South Total	*282,405*	*315,111*	*301,296*	*127,813*	*167,469*	*154,925*
West						
50	46,376	53,908	56,394	22,911	30,265	27,336
53	17,301	26,390	26,614	3,655	8,436	7,575
72	29,728	34,100	34,998	14,954	20,500	17,291
West Total	*93,405*	*114,398*	*118,006*	*41,520*	*59,201*	*52,202*
Total	**1,530,873**	**1,665,106**	**1,615,157**	**956,009**	**1,087,798**	**1,038,189**

Source: AECOM, 2011; HDR Inc, 2011.

Person Trips

Table 3 summarizes the person trips and other key data from AECOM's Calibration, and Opening Year, and HDR Opening Year model runs. The person trips were organized into super districts for further analysis and are shown in **Table 4**. The review of the person trips identifies the following:

- Overall, there are fewer person trips in AECOM's Opening Year model run that were subjected to Mode Choice than the other two model runs. However, the total number of person trips prior to Mode Choice were about 8 percent higher in AECOM's Opening Year run than HDR's Opening Year run. *It is not clear why nearly 890,250 trips[13] in AECOM's Opening Year run were not subjected to Mode Choice.*
- In general, there are fewer person trips traveling from the Core, Corridor, East, and North super districts in AECOM's Opening Year model run than their Calibration Year model and HDR's Opening Year model run.
- In terms of the distribution of trips from various districts to CBD and the study corridor, there are some minor differences among the three model runs. But those differences are directly attributable to the differences in demographic, land use and network assumptions.

[13] In Complex Commute trip category

Table 3: Summary of Model Results

Network and demographic assumptions					
Demographics	**Year 2000**	**Year 2011**			**Year 2009**
Highway network	**Year 2000**	**Year 2011**			**Year 2010**
Transit network	**Year 2000**	**Year 2011**			**Year 2011**
TIDE LRT	**N/A**	**TIDE included**			**TIDE included**
TIDE LRT Headway	**N/A**	**7.5/15**			**10/15**
	AECOM's Calibration Year model run	**AECOM's Opening year model run**	**2010 Observed data from HRT (Sept 2010)**		**HDR's opening year model run**
Total population	1,530,873	1,665,106			1,615,157
Total employment	956,009	1,087,798			1,038,189
Person trips					
HBW	992,803	795,964 *			1,072,548
HBO	3,288,158	3,566,107 *			3,480,403
NHB	1,735,215	1,641,045 *			1,844,653
Total person trips	**6,016,176**	**6,003,116** *			**6,397,604**
MODE CHOICE SUMMARY					
Total Walk to Local Transit	29,623	25,941			22,888
Total Walk to Premium Transit	0	1,402			1,323
Total Drive to Local Transit	121	167			180
Total Drive to Premium Transit	0	415			965
Total Fringe-Parking to Transit	896	881			995
Total SOV Person Trips	3,727,028	3,670,414			3,976,558
Total HOV Person Trips	2,254,774	2,300,828			2,392,155
Total Fringe-Parking to Walk	1,450	1,648			1,929
Total Fringe-Parking to Shuttle	2,516	1,618			692
TOTAL TRANSIT TRIPS (linked trips)	**33,157**	**30,424**			**27,042**
TOTAL MODE SPLIT (Percent)	0.55%	0.51%			0.42%
Unlinked transit trips (boardings)	**35,778**	**34,377**	**52,750**		**31,900**
TIDE ridership		**2,537**	**5,300**		**2,870**
Express Bus ridership	**180**	**166**	**1,500**		**274**

*** does not include Complex Commute trips**

Source: AECOM 2011, HDR Inc 2011

Table 4: Person Trips

		CBD	Core	Corridor	East	North	Penninsula	South	West	Total
	AECOM Calibration Yr	2,762	4,247	2,821	4,851	5,210	139	2,207	70	**22,306**
CBD	AECOM Opening Yr	3,614	4,079	2,561	4,810	5,744	705	2,891	277	**24,681**
	HDR Opening Yr	2,741	4,578	2,915	5,398	6,849	187	2,323	74	**25,065**
	AECOM Calibration Yr	9,733	52,342	14,059	24,068	37,267	2,185	37,940	1,680	**179,274**
CORE	AECOM Opening Yr	8,688	58,422	9,936	19,146	29,574	4,884	49,666	3,021	**183,338**
	HDR Opening Yr	9,214	46,740	13,579	28,133	39,807	2,330	42,621	1,995	**184,419**
	AECOM Calibration Yr	6,439	12,271	23,116	37,162	31,506	1,041	10,681	356	**122,571**
CORRIDOR	AECOM Opening Yr	5,275	8,769	20,055	28,861	24,273	2,003	9,078	680	**98,993**
	HDR Opening Yr	6,687	13,829	21,564	39,395	35,067	1,113	11,756	365	**129,776**
	AECOM Calibration Yr	22,333	39,132	69,014	1,406,671	165,483	14,334	128,878	5,203	**1,851,049**
EAST	AECOM Opening Yr	17,035	26,928	53,566	1,257,017	109,286	27,120	119,666	10,155	**1,620,774**
	HDR Opening Yr	21,125	42,751	65,475	1,445,874	165,463	12,923	147,308	5,382	**1,906,301**
	AECOM Calibration Yr	16,760	51,725	46,580	134,064	441,255	13,091	36,438	1,888	**741,800**
NORTH	AECOM Opening Yr	15,831	39,962	37,116	100,534	375,228	20,486	31,202	4,149	**624,509**
	HDR Opening Yr	19,070	53,440	48,499	141,101	415,661	11,575	37,304	1,731	**728,381**
	AECOM Calibration Yr	1,665	5,113	3,064	15,748	25,276	1,936,347	15,321	12,823	**2,015,357**
PENNINSULA	AECOM Opening Yr	1,333	3,704	1,910	17,038	12,834	2,052,563	16,764	19,538	**2,125,683**
	HDR Opening Yr	2,259	6,179	3,138	16,531	26,473	2,088,902	17,090	16,715	**2,177,287**
	AECOM Calibration Yr	15,474	83,749	29,080	165,027	69,677	24,020	497,963	23,046	**908,036**
SOUTH	AECOM Opening Yr	12,430	80,708	22,481	156,051	47,814	42,333	654,397	40,718	**1,056,930**
	HDR Opening Yr	14,673	86,602	28,856	201,443	71,265	23,495	559,796	29,569	**1,015,699**
	AECOM Calibration Yr	1,338	7,056	1,854	9,026	5,612	20,527	26,431	103,969	**175,814**
WEST	AECOM Opening Yr	1,087	5,047	1,226	9,409	4,351	30,657	31,632	184,800	**268,207**
	HDR Opening Yr	1,478	8,390	1,990	12,226	6,450	29,889	38,027	132,226	**230,676**
Total	**AECOM Calibration Yr**	76,505	255,635	189,587	1,796,619	781,288	2,011,682	755,859	149,035	**6,016,210**
Total	**AECOM Opening Yr**	65,291	227,619	148,851	1,592,866	609,104	2,180,750	915,297	263,338	**6,003,116**
Total	**HDR Opening Yr**	77,247	262,509	186,016	1,890,101	767,035	2,170,414	856,225	188,057	**6,397,604**

Source: AECOM, 2011; HDR Inc, 2011.

Transit Trips

Table 5 summarizes the transit trips organized into super districts. The following conclusions can be made from this review:

- Overall, the HDR Opening Year run has fewer transit trips when compared to AECOM's Calibration and Opening Year model runs.
- There are significantly fewer transit trips from the East super district in the HDR Opening model run when compared to the other two model runs.
- There are significantly more transit trips from the Peninsula super district in the HDR Opening model run when compared to the other two model runs.
- In general, the differences in transit trips among the three model runs can be attributed to the underlying network assumptions and socio-economic inputs.

Table 5: Transit Trips

		CBD	Core	Corridor	East	North	Penninsula	South	West	Total
	AECOM Calibration Yr	201	122	76	13	77		6		**496**
CBD	AECOM Opening Yr	271	118	73	13	89		9		**573**
	HDR Opening Yr	173	109	72	11	50		5		**421**
	AECOM Calibration Yr	774	1,239	301	47	405		198		**2,964**
CORE	AECOM Opening Yr	979	1,227	230	44	387		221		**3,089**
	HDR Opening Yr	668	1,082	287	43	383		170	1	**2,634**
	AECOM Calibration Yr	558	258	598	201	380		32		**2,027**
CORRIDOR	AECOM Opening Yr	642	215	583	186	357		22		**2,005**
	HDR Opening Yr	527	353	491	150	331		23		**1,876**
	AECOM Calibration Yr	1,909	273	500	5,841	377		138		**9,037**
EAST	AECOM Opening Yr	1,738	228	571	4,949	339	0	78		**7,903**
	HDR Opening Yr	1,122	421	348	2,779	239		24		**4,934**
	AECOM Calibration Yr	1,532	931	781	317	4,904		40		**8,505**
NORTH	AECOM Opening Yr	1,716	809	699	326	4,806	1	22		**8,378**
	HDR Opening Yr	1,150	1,008	671	241	3,543	2	25		**6,639**
	AECOM Calibration Yr				1		7,820	1		**7,822**
PENNINSULA	AECOM Opening Yr				0		6,578			**6,578**
	HDR Opening Yr	14		2		40	9,167	2		**9,226**
	AECOM Calibration Yr	1,504	718	160	73	76	1	934	4	**3,471**
SOUTH	AECOM Opening Yr	1,278	634	96	71	80	1	941	9	**3,110**
	HDR Opening Yr	1,026	686	127	40	104	1	685	8	**2,678**
	AECOM Calibration Yr							8	2	**10**
WEST	AECOM Opening Yr							8	226	**234**
	HDR Opening Yr		4				1	13	146	**164**
Total	**AECOM Calibration Yr**	**6,479**	**3,541**	**2,416**	**6,492**	**6,219**	**7,821**	**1,358**	**7**	**34,333**
Total	**AECOM Opening Yr**	**6,625**	**3,230**	**2,254**	**5,589**	**6,058**	**6,580**	**1,300**	**235**	**31,870**
Total	**HDR Opening Yr**	**4,680**	**3,663**	**1,999**	**3,264**	**4,690**	**9,171**	**947**	**155**	**28,570**

Source: AECOM, 2011; HDR Inc, 2011.

Revenue Miles

After a review of the transit trips, revenue miles for all transit services in each model were calculated. The purpose of calculating revenue miles was to understand the level of transit service provided in each model. **Table 6** shows the revenue miles for each model run at the system level as well as the service provided in the East and Peninsula super district. **Figures 2, 3,** and **4** depict the transit routes provided system wide, in the East super district, and the Peninsula super district, respectively. Overall, there are approximately 3,000 more revenue miles provided in the HDR Opening model run than the other two model runs. However, in the East super district, there are approximately 3,000 fewer revenue miles in the HDR Opening model compared to the other two model runs. This may explain why there is a lower number of transit trips from the East super district in the HDR Opening model run. In the Peninsula super district, there are approximately 5,000 more revenue miles in the HDR Opening model when compared to the other two model runs, which may explain the increase in transit trips from the Peninsula super district.

Table 6: Revenue Miles

	System Wide			East			Peninsula		
	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total
AECOM's Calibration	13,966.0	23,872.8	37,838.8	5,592.4	8,503.2	14,095.6	4,634.4	9,326.4	13,960.8
AECOM's Opening Year	16,546.8	22,812.0	39,358.8	5,334.0	9,477.6	14,811.6	6,370.8	6,662.4	13,033.2
HDR Opening Year	17,220.8	25,016.4	42,237.2	4,596.0	7,231.2	11,827.2	8,328.8	10,652.4	18,981.2

Source: AECOM, 2011; HDR Inc, 2011.

Figure 2: System Wide Transit Routes

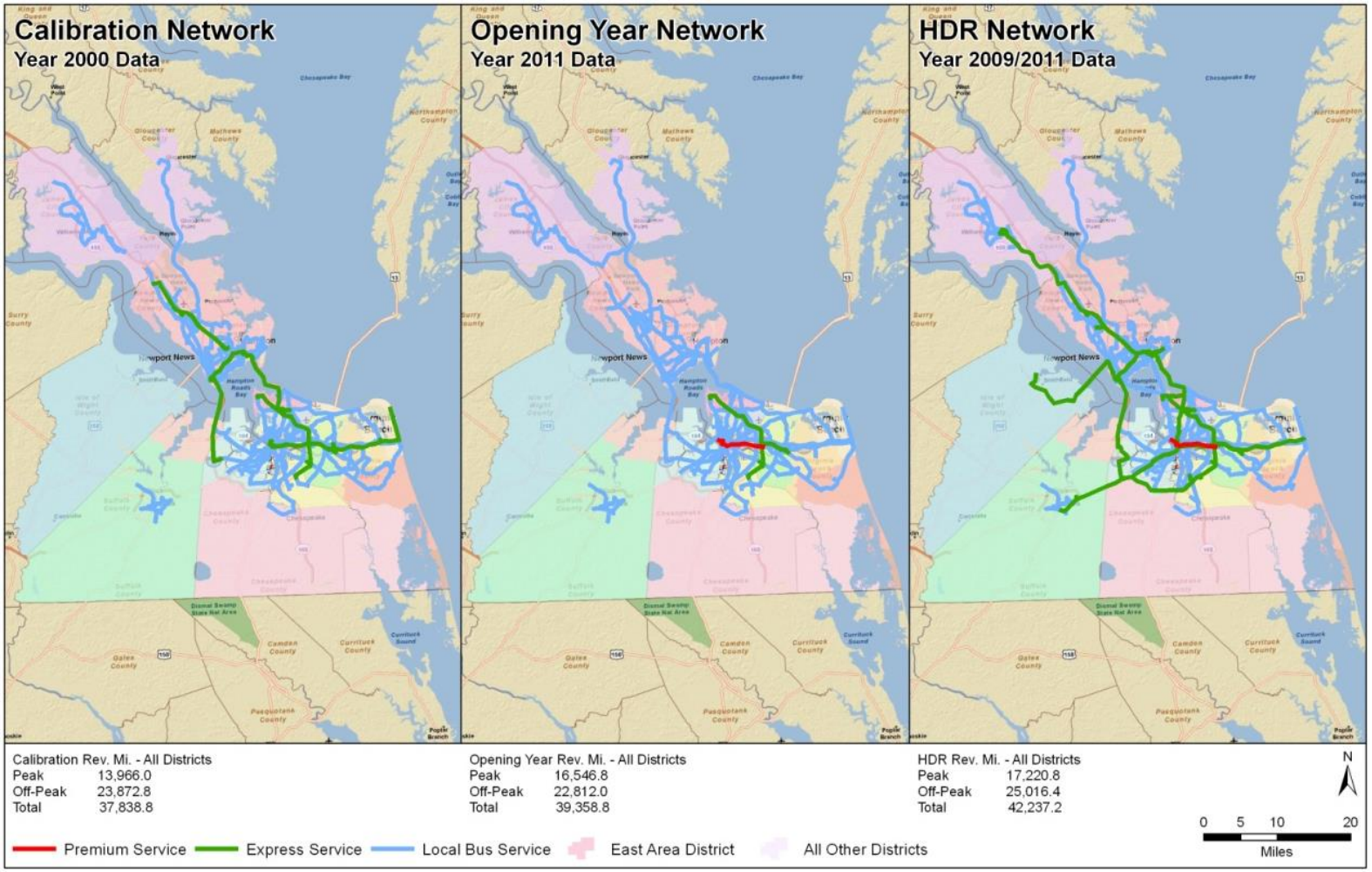


Figure 3: East Area Transit Routes

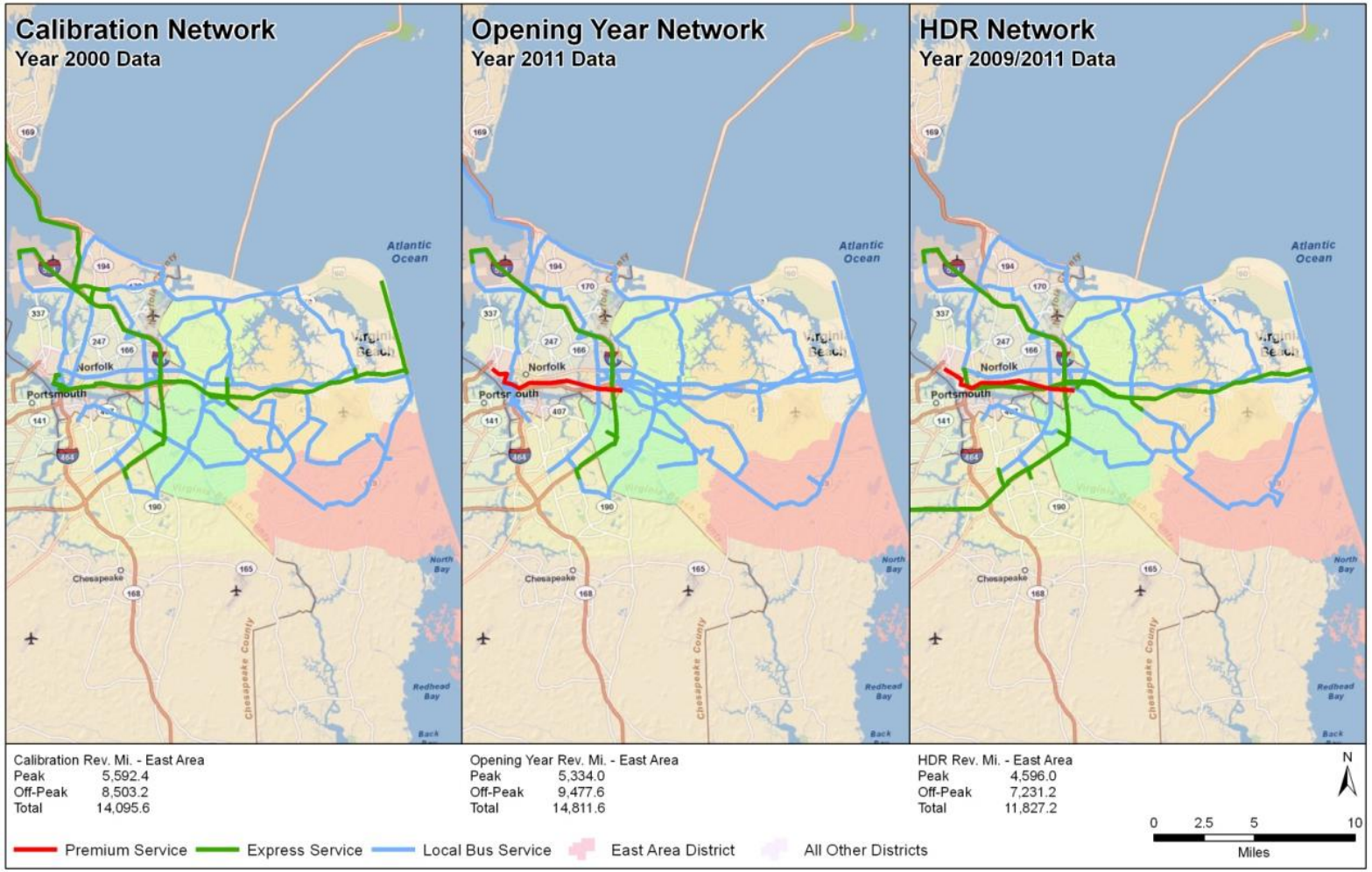


Figure 4: Peninsula Transit Routes

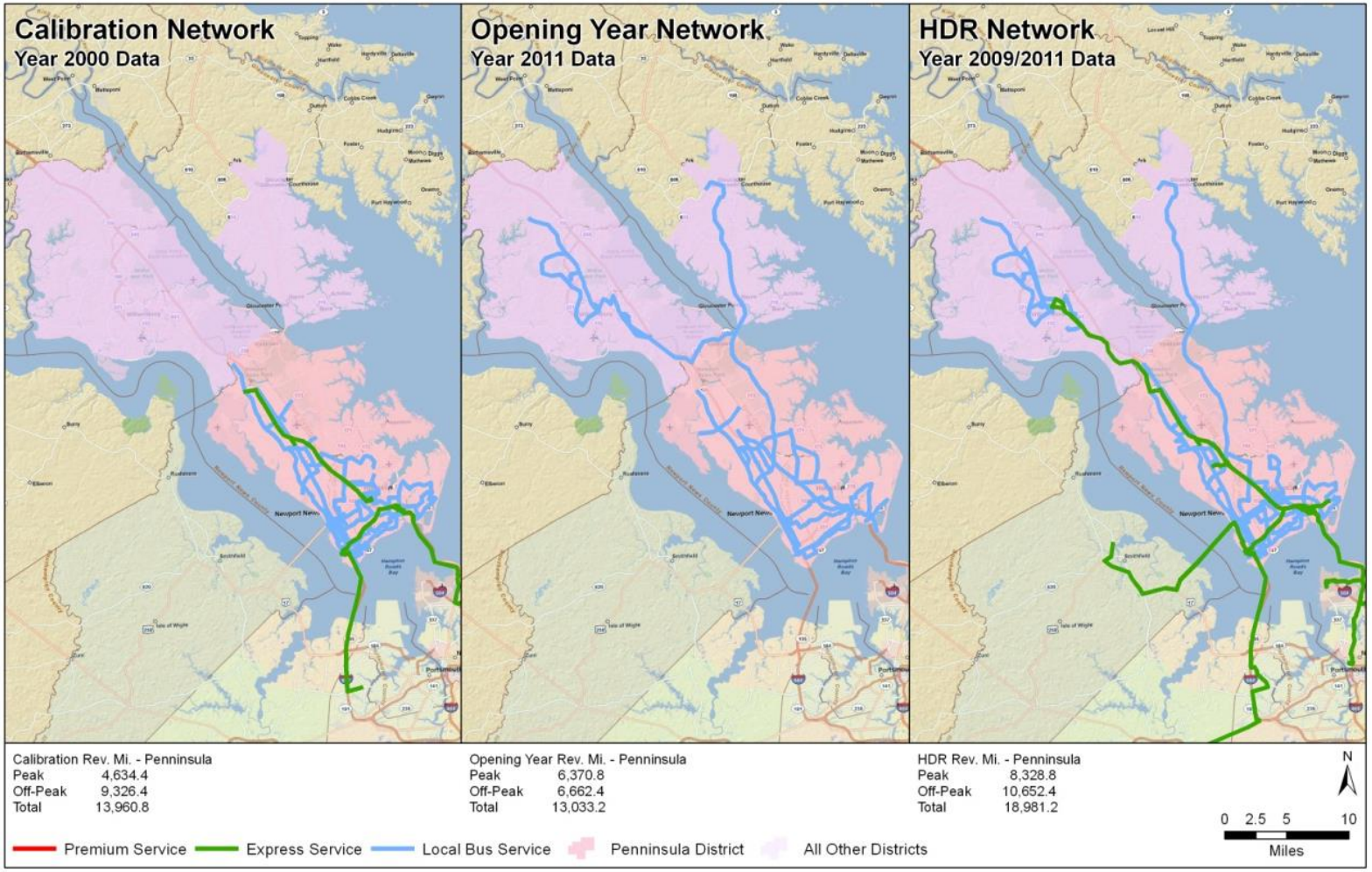


Table 7 summarizes the revenue miles coded in the three model runs. As seen, AECOM's Opening Year run contains significantly less service for the Express mode and a lot more service for the local bus mode.

Table 7: Revenue Miles by Transit Sub-mode

Mode	Type	AECOM's Calibration Year run	AECOM's Opening Year run	HDR's Opening Year run
1	Local	20,078.4	24,338.4	18,027.6
2	Peninsula Local	11,896.8	11,355.6	15,812.6
3	VBeach	0.0	1,202.4	673.2
4	Ferry Service	64.8	64.8	64.8
5	Parking Shuttle* (Route 17)	1,152.0	192.0	0.0
6	Premium (LRT)	0.0	1,411.2	1,234.8
9	Express	4,646.8	794.4	6,424.2
Total		**37,838.8**	**39,358.8**	**42,237.2**

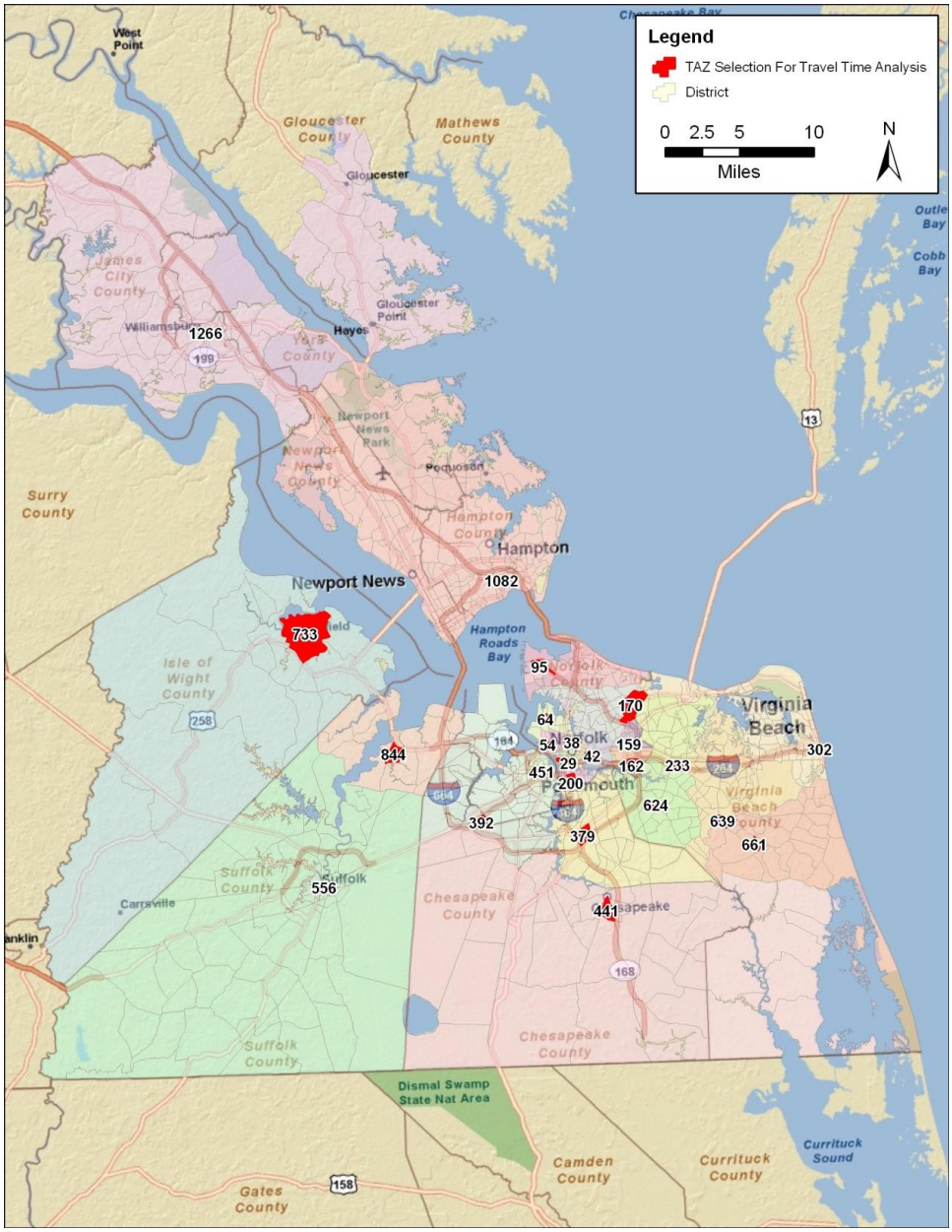
Source: HDR Inc

***Note**: The Route 17 parking shuttle varied by model. In the Calibration model, the route was 3.2 miles in length and operated on an all day headway of 6 minutes. In the AECOM Opening model, the route was one mile long with a 7.5-minute peak and 15-minute off-peak. In the HDR Opening model, the route was approximately 3.8 miles and operates on an all day headway of 15 minutes. In this model, the Route 15 was classified as a "Local" mode and therefore, the revenue miles are not identified in the "Parking Shuttle" mode.

Travel Times

Travel times for drive alone and transit were extracted from the highway and transit skim files and compared. Skims were acquired at the origin end for one TAZ in each district to the destination end which was downtown Norfolk, TAZ 5. Figure 5 identifies the origin TAZs that were used to acquire the travel times to downtown Norfolk.

Figure 5: TAZ Selected for Travel Time Analysis



Source: HDR, Inc.

Drive Alone Travel Times

Table 8 identifies the drive alone travel times from each district to downtown Norfolk. Overall, the travel times between AECOM's Calibration Year model run and HDR's Opening Year run are comparable. AECOM's Opening Year model run, in general has faster travel times than the other two model runs. It is not clear why the off-peak travel times in many cases are worse than peak travel times in all three model runs.

Table 8: Drive Alone Travel Times to Downtown Norfolk/MacArthur LRT Station (TAZ 5)

District	TAZ	Location	Peak Period (minutes)			Off-Peak Period (minutes)		
			AECOM's Calibration Year	AECOM's Opening Year	HDR Opening Year	AECOM's Calibration Year	AECOM's Opening Year	HDR Opening Year
CBD								
33	4	Civic Plaza LRT Station	1.1	1.1	1.3	1.1	1.1	1.1
Core								
31	200	Berkley Ave	3.6	3.5	3.9	7.9	7.9	7.9
34	54	EVMC LRT Station	3.7	3.9	4.0	2.8	2.8	2.8
40	451	Portsmouth	5.5	6.1	4.8	12.3	12.3	13.8
98	38	Tidewater Dr/Goff St	4.4	4.1	4.5	3.2	3.2	3.2
Corridor								
29	162	Military Hwy LRT Station	10.4	9.8	10.9	7.1	7.1	7.1
30	42	Ballentine LRT Station	5.1	4.9	5.3	3.6	3.6	3.6
32	29	Harbor Park LRT Station	1.4	1.4	1.6	1.4	1.4	1.4
East								
60	302	Virginia Beach	34.5	29.6	34.7	20.4	20.5	20.6
61	233	Witchduck/I-264	21.7	19.1	21.4	11.6	11.6	11.6
65	661	N. Landing/Princess Anne Rd	41.0	39.1	47.9	21.5	22.2	21.5
66	639	Tidewater Comm College	33.9	32.0	37.6	17.6	17.6	17.6
67	624	Kempsville Rd/Indian River Rd	19.7	17.4	20.5	10.4	10.4	10.4
North								
20	95	Norfolk Naval Station	18.9	17.1	19.7	11.3	11.3	11.4
23	170	Norfolk Int'l Airport	17.2	15.9	17.7	10.9	10.9	10.9
26	64	Old Dominion Univ.	10.1	9.5	10.6	6.0	6.0	5.9
99	159	VB Blvd/Military Hwy	11.1	10.6	11.2	7.4	7.4	7.3
Peninsula								
125	1082	Hampton	30.1	32.1	29.5	35.5	35.5	35.4
140	1266	Williamsburg	80.3	86.5	77.4	63.0	63.0	63.6
South								
1	379	I-464/I-64	9.9	10.2	10.6	13.8	13.8	13.9
10	441	Chesapeake	20.4	21.9	22.2	20.0	20.5	19.9
42	392	I-64/I-264	12.0	12.5	11.2	17.9	17.9	20.1
West								
50	556	Suffolk	28.6	31.3	31.4	30.4	30.4	33.3
53	844	US-17/Bennetts Pasture Rd	25.7	23.2	20.8	27.1	27.1	31.6
72	733	Smithfield	40.9	40.6	39.1	42.7	42.7	47.9

Source: AECOM, 2011; HDR Inc, 2011.

Transit Travel Times

Table 9 and **Table 10** show the transit travel times from each district to downtown Norfolk for both local bus and premium transit. Transit travel times are the sum of the transit time, the transit wait time, and the walk time.

A review of the transit travel times concludes the following:

Overall, travel times for walk to local bus in the peak appear to be longer in the HDR Opening year model when compared to the Calibration and Opening Year model run.

The travel time for walk to premium transit is longer in the HDR Opening model than the Opening Year model. The updated transit network embedded in HDR's opening year run seems to generate more transit paths and therefore more skims than the other two model runs.

Table 9: Local Bus Transit Travel Times to Downtown Norfolk/MacArthur LRT Station (TAZ 5)

District	TAZ	Location	Walk to Local Bus Peak (minutes)		
			Calibration	Opening Year	HDR Opening
CBD					
33	4	Civic Plaza LRT Station	9.9	17.9	15.1
Core					
31	200	Berkley Ave	42.6	43.8	38.8
34	54	EVMC LRT Station	29.1	31.4	35.6
40	451	Portsmouth	28.3	26.5	32.2
98	38	Tidewater Dr/Goff St	29.0	28.2	27.0
Corridor					
29	162	Military Hwy LRT Station	74.9	81.4	86.0
30	42	Ballentine LRT Station	31.5	35.6	43.2
32	29	Harbor Park LRT Station	19.2	24.7	24.4
East					
60	302	Virginia Beach	61.8	138.7	156.0
61	233	Witchduck/I-264	117.7	93.2	136.4
65	661	N. Landing/Princess Anne Rd	0.0	0.0	0.0
66	639	Tidewater Comm College	150.9	154.7	0.0
67	624	Kempsville Rd/Indian River Rd	91.8	90.5	103.3
North					
20	95	Norfolk Naval Station	69.8	66.7	86.7
23	170	Norfolk Int'l Airport	0.0	0.0	0.0
26	64	Old Dominion Univ.	41.1	40.2	54.0
99	159	VB Blvd/Military Hwy	57.3	59.4	65.4
Peninsula					
125	1082	Hampton	138.9	128.8	90.2
140	1266	Williamsburg	0.0	0.0	0.0
South					
1	379	I-464/I-64	67.2	75.6	77.7
10	441	Chesapeake	0.0	0.0	0.0
42	392	I-64/I-264	0.0	0.0	0.0
West					
50	556	Suffolk	0.0	0.0	0.0
53	844	US-17/Bennetts Pasture Rd	0.0	0.0	0.0
72	733	Smithfield	0.0	0.0	0.0

Source: AECOM, 2011; HDR Inc, 2011.

Table 10: Premium Mode Transit Travel Times to Downtown Norfolk/MacArthur LRT Station (TAZ 5)

District	TAZ	Location	Walk to Premium-Peak Period (minutes)			Drive to Premium-Peak Period (minutes)		
			Calibration	Opening Year	HDR Opening	Calibration	Opening Year	HDR Opening
CBD								
33	4	Civic Plaza LRT Station	0.0	0.0	0.0	0.0	0.0	23.1
Core								
31	200	Berkley Ave	0.0	0.0	0.0	0.0	0.0	28.8
34	54	EVMC LRT Station	0.0	32.8	35.4	0.0	0.0	34.4
40	451	Portsmouth	0.0	0.0	0.0	0.0	0.0	30.4
98	38	Tidewater Dr/Goff St	0.0	0.0	0.0	0.0	0.0	35.3
Corridor								
29	162	Military Hwy LRT Station	0.0	57.3	61.0	0.0	35.3	39.5
30	42	Ballentine LRT Station	0.0	28.3	31.4	0.0	0.0	28.7
32	29	Harbor Park LRT Station	0.0	0.0	18.4	0.0	0.0	24.0
East								
60	302	Virginia Beach	0.0	76.8	135.0	0.0	59.6	70.7
61	233	Witchduck/I-264	0.0	60.1	115.4	0.0	41.5	50.5
65	661	N. Landing/Princess Anne Rd	0.0	0.0	145.5	0.0	0.0	0.0
66	639	Tidewater Comm College	0.0	121.5	133.3	0.0	0.0	0.0
67	624	Kempsville Rd/Indian River Rd	0.0	88.6	0.0	0.0	53.1	65.4
North								
20	95	Norfolk Naval Station	0.0	0.0	88.6	0.0	0.0	0.0
23	170	Norfolk Int'l Airport	0.0	0.0	0.0	0.0	56.4	64.0
26	64	Old Dominion Univ.	0.0	0.0	55.8	0.0	0.0	56.4
99	159	VB Blvd/Military Hwy	0.0	54.7	63.5	0.0	39.3	42.2
Peninsula								
125	1082	Hampton	0.0	0.0	0.0	0.0	0.0	0.0
140	1266	Williamsburg	0.0	0.0	0.0	0.0	0.0	0.0
South								
1	379	I-464/I-64	0.0	0.0	0.0	0.0	0.0	45.2
10	441	Chesapeake	0.0	0.0	0.0	0.0	0.0	0.0
42	392	I-64/I-264	0.0	0.0	0.0	0.0	0.0	43.5
West								
50	556	Suffolk	0.0	0.0	0.0	0.0	0.0	0.0
53	844	US-17/Bennetts Pasture Rd	0.0	0.0	0.0	0.0	0.0	0.0
72	733	Smithfield	0.0	0.0	0.0	0.0	0.0	0.0

Source: AECOM, 2011; HDR Inc, 2011.

Conclusions

The diagnostic evaluation of the model inputs and outputs resulted in the following conclusions.

- The total transit demand in the AECOM's Calibration Year model run was calibrated to a much lower number than the actual ridership in 2000. According to the NTD ridership data reported by HRT to the FTA, there were approximately 58,000 boardings in the transit system in 2003. AECOM's Calibration Year model produced only 34,400 boardings for the calibration year 2003.
- The magnitude of the population and employment data used in all three model runs appear reasonable.

- There are minor differences in the distribution of total person trips and transit person trips among the three model runs but they did not contribute to the overall underestimation of the transit demand in the system.
- There are moderate differences in the transit network among all the three model runs but they did not contribute to the overall underestimation of the transit demand in the system
- The highway travel times in all the three model runs are comparable. The off-peak travel times appear to be counter-intuitive in many cases.
- There are some minor to moderate differences in transit travel times among the three model runs but they did not contribute to the overall underestimation of the transit demand in the system

Context and Recommendations for Further Enhancements

This analysis continues to illustrate that the transit portion of the HRPDC model is in significant need of revision, re-calibration, or overall replacement to be an accurate forecasting tool. The inconsistencies between model runs illustrated in the above analysis are to some extent to be expected since the model was re-calibrated and modified over a number of years in incremental steps to try and be sensitive to the myriad of changes in the region and also address FTA's concerns during the TIDE project planning and development phase. However, without more complete documentation of logic behind the changes it is unclear what the purpose of the changes was, who initiated them, or the resultant predicted travel patterns.
It is worth noting it appears that there was significant uncertainty surrounding the calibration of existing transit model. Based on our research, it appears that the calibration targets were not linked to an on-board survey trip table and there were (and continue to be) significant uncertainties about the ridecount and boardings that were used. Numerous incremental steps were taken by HRT and their consultants to attempt to minimize this uncertainty, but that combined with approximately 10 years of change in Hampton Roads have led to a forecasting tool that no longer appears to accurately represent regional transit travel patterns.

Therefore a significant model update/re-calibration/replacement effort is warranted at this time. The region is fortunate that now it has a comprehensive set of on-board surveys taken in 2009, 2010, and 2011, along with detailed APC and ridership count information from which to develop rigorous survey-based trip tables. These in turn provide an excellent basis for calibration trip targets. When coupled with a more accurate representation of transit travel speeds, these changes can provide more confident forecasts.

It should also be noted that in the past the transit model developed by HRT and the regional travel demand model developed by the HRTPO were, while children of a common mother, significantly different in terms of mode choice and trip assignment (most notably in the HRT versions ability to compute the FTA TSUB measure). At the present time, VDOT and HRTPO are engaged in a comprehensive top-to-bottom replacement/revision of their basic model application and structure. In addition to being revised to use some of the advanced features of the latest version of CUBE software, the revised regional model is also taking advantage of

some of the HRT-model features (such as the detailed choice set including the Fringe Parking choices).

Because of this, it is of critical interest to HRT to coordinate with HRTPO and VDOT (who is responsible for the development of the model application) to see if there are opportunities to take advantage of each others' efforts.

Appendix K-3

Technical Memorandum dated 4/26/2012

To: **Ray Amoruso, Karen Waterman, Hampton Roads Transit**

From: **Vijay Mahal and Nick Karcz, Mike Rose HDR Inc**

Copy: **Eric Nelson, Pete Mazurek HDR Inc**

Date: **4/26/2012**

Subject: **VBTES WA #11: Replicate 2009 Base Model run using VDOT's new travel model**

Introduction

The purpose of this memorandum is to report the results of Subtask 1.1 of the Virginia Beach Transit Extension Study- Work Authorization #11. As part of this task, we obtained the new VDOT/HRTPO model and all the related inputs from VDOT's consultants (AECOM) and conducted a test run to replicate the calibration results of the 2009 base year condition. From the outputs of the model run, we summarized the results of trip generation, trip distribution, mode choice and the transit assignment models and compared the results with those generated by VDOT's consultants. The finding was we were able to match the results of all the sub models accurately with AECOM's 2009 calibration model results. As part of this task, we also verified the bus running times for every single route in the modeled network and other operational performance as coded.

Results of Model Replication

Presented in **Table 1** are the results of the Mode Choice model. As seen we matched the calibration run with 100 percent accuracy. The matching of Mode Choice model run implies we replicated the Trip Generation and Distribution sub models too.

Table 1: 2009 Calibration Run and HDR Run Mode Choice Summary

Mode Choice	AECOM's 2009 Calibration Run	HDR's replication of 2009 Run	Difference
HBW			
Drive Alone	730,554.31	730,554.31	0
Shared Ride 2	78,826.95	78,826.95	0
Shared Ride 3	30,603.74	30,603.74	0
Walk Transit	20,792.08	20,792.08	0
Drive Transit	584.66	584.66	0
Fringe Park-Walk	1,937.60	1,937.60	0
Fringe Park-Drive	870.98	870.98	0

Fringe Park-Shuttle	2,859.78	2,859.78	0
Total	**867,030.10**	**867,030.10**	***0***
HBO			
Drive Alone	1,314,814.57	1,314,814.57	0
Shared Ride 2	1,044,897.21	1,044,897.21	0
Shared Ride 3	681,521.86	681,521.86	0
Walk Transit	14,924.41	14,924.41	0
Drive Transit	153.83	153.83	0
Total	**3,056,311.88**	**3,056,311.88**	***0***
NHB			
Drive Alone	1,737,111.00	1,737,111.00	0
Shared Ride 2	898,737.30	898,737.30	0
Shared Ride 3	555,688.90	555,688.90	0
Walk Transit	3,737.30	3,737.30	0
Total	**3,195,274.50**	**3,195,274.50**	***0***

Presented in **Table 2** are the results of the Transit assignment model.

Table 2: 2009 Calibration Run and HDR Run Transit Summary

Transit File	AECOM's 2009 Calibration Run	HDR's replication of 2009 Run	Difference
LINKDPK.dbf	291.63	291.63	0
LINKWPK.dbf	26,787.62	26,787.62	0
LINKFSHTPK.dbf	1,059.68	1,059.68	0
LINKFTRNPK.dbf	1,119.00	1,119.00	0
LINKDOP.dbf	621.29	621.29	0
LINKWOP.dbf	25,653.33	25,653.33	0
Total	***55,532.55***	***55,532.55***	***0***

Comparison of coded headways and travel times

Tables 3 and 4 present a summary of our comparison of headways and travel times coded in the 2009 Calibration run with the actual scheduled headways and travel times. For most part, the coded data in the model match accurately with the schedules. However. there are six routes in the South Peninsula local service (Route 11, 15, 1, 25, 27 and 3) whose coded headways are significantly different from scheduled headways. They will need to be adjusted. All headways in the Peninsula routes matched well. On the express routes, the coded headways on Routes 922, 962 and 967 will need to be adjusted.

The coded travel times vary significantly from the scheduled travel times on most routes. In CUBE software, it is possible to force the computed travel time to scheduled times. We recommend that the travel times be fixed and the model be re-calibrated.

Table 3: Comparison of Headways by Route

Route Name	2009 Model Run		2012 Bus Schedules	
	Headways		Headways	
	Peak	Off-Peak	Peak	Off-Peak
Southside Local Service (Mode 1)				
HRT11	30	30	60	60
HRT11_rev	30	30	60	60
HRT12	60	60	60	60
HRT12_rev	60	60	60	60
HRT13A	60	60	60	60
HRT13A_rev	60	60	60	60
HRT13B	60	60	60	60
HRT13B_rev	60	60	60	60
HRT15A	60	60	30	30
HRT15A_rev	60	60	30	30
HRT15B	60	60	30	0
HRT15B_rev	60	60	30	0
HRT18	60	60	60	60
HRT18_rev	60	60	60	60
HRT1A	60	60	60	60
HRT1A_rev	60	60	60	60
HRT1B	30	0	60	0
HRT1B_rev	30	0	60	0
HRT1C	30	0	30	0
HRT1C_rev	30	0	30	0
HRT2	30	30	30	30
HRT2 _rev	30	30	30	30
HRT20A	30	30	30	30
HRT20A_rev	30	30	30	30
HRT20B	30	0	30	0
HRT20B_rev	30	0	30	0
HRT23	30	30	30	30
HRT23_rev	30	30	30	30
HRT25	30	30	60	60
HRT25_rev	30	30	60	60
HRT26A	60	60	60	60
HRT26A_rev	60	60	60	60
HRT26B	60	60	60	60
HRT26B_rev	60	60	60	60
HRT27	60	60	30	60
HRT27_rev	60	60	30	60
HRT29	60	60	60	60
HRT29_rev	60	60	60	60
HRT33	60	60	60	60
HRT33_rev	60	60	60	60
HRT3A	60	60	60	60
HRT3A_rev	60	60	60	60

HRT3B	60	60	20	60
HRT3B_rev	60	60	20	60
HRT4	60	60	60	60
HRT4 _rev	60	60	60	60
HRT41	60	60	60	60
HRT41_rev	60	60	60	60
HRT44A	60	60	60	60
HRT44A_rev	60	60	60	60
HRT45	30	30	30	30
HRT45_rev	30	30	30	30
HRT47	30	30	30	30
HRT47_rev	30	30	30	30
HRT5	60	60	60	60
HRT5 _rev	60	60	60	60
HRT50	60	60	60	60
HRT50_rev	60	60	60	60
HRT57	60	60	60	60
HRT57_rev	60	60	60	60
HRT58	60	60	60	60
HRT58_rev	60	60	60	60
HRT6A	60	60	60	60
HRT6A_rev	60	60	60	60
HRT6C	60	60	60	60
HRT6C_rev	60	60	60	60
HRT8	30	30	30	30
HRT8 _rev	30	30	30	30
HRT9	30	30	30	30
HRT9 _rev	30	30	30	30
Peninsula Local Service (Mode 2)				
HRT64	60	60	60	0
HRT64_rev	60	60	60	0
PTRN101	35	35	35	35
PTRN101_rev	35	35	35	35
PTRN102	60	60	60	60
PTRN102_rev	60	60	60	60
PTRN103	30	30	30	30
PTRN103_rev	30	30	30	30
PTRN104	30	30	30	30
PTRN104_rev	30	30	30	30
PTRN105	60	60	60	60
PTRN105_rev	60	60	60	60
PTRN106	60	60	60	60
PTRN106_rev	60	60	60	60
PTRN107	60	60	60	60
PTRN107_rev	60	60	60	60
PTRN109	60	60	60	60
PTRN109_rev	60	60	60	60
PTRN110	60	60	60	60

PTRN110_rev	60	60	60	60
PTRN111	60	60	60	60
PTRN111_rev	60	60	60	60
PTRN112	30	30	30	30
PTRN112_rev	30	30	30	30
PTRN114	30	30	30	30
PTRN114_rev	30	30	30	30
PTRN115	30	30	60	60
PTRN115_rev	30	30	60	60
PTRN117B	60	60	60	60
PTRN117B_rev	60	60	60	60
PTRN118	60	60	60	60
PTRN118_rev	60	60	60	60
PTRN119	40	40	40	40
PTRN119_rev	40	40	40	40
PTRN120	60	60	60	60
PTRN120_rev	60	60	60	60
MAX Service (Mode 9)				
MAX918	90	0	90	0
MAX919	33	0	25	0
MAX922	36	0	20	0
MAX960	60	60	60	60
MAX961	30	60	30	60
MAX961_rev	30	60	30	60
MAX962	30	0	60	0
MAX962_rev	30	0	60	0
MAX967N	30	0	22.5	0
MAX967S	60	0	30	0

Table 4: Comparison of Travel Times by Route

Route Name	2009 Model Run		2012 Bus Schedules	Difference
	Travel Time (min)		Travel Time (min)	2012 Schedule time vs. 2009 Model
	Peak	Off-Peak	Average	
Southside Local Service (Mode 1)				
HRT11	12.5	12.9	17.0	35%
HRT11_rev	12.0	12.4	17.0	41%
HRT12	49.7	46.2	57.0	15%
HRT12_rev	49.6	47.0	57.0	15%
HRT13A	59.5	57.3	50.8	-15%
HRT13A_rev	62.1	56.9	50.8	-18%
HRT13B	21.0	21.7	22.2	6%
HRT13B_rev	22.9	22.3	22.2	-3%
HRT15A	80.6	77.7	109.2	36%
HRT15A_rev	81.9	78.8	109.2	33%
HRT15B	50.2	46.8	57.9	15%
HRT15B_rev	50.0	47.1	57.9	16%
HRT18	18.6	17.9	29.3	57%

HRT18_rev	18.2	17.9	29.3	61%
HRT1A	79.8	78.6	91.2	14%
HRT1A_rev	80.1	78.4	91.2	14%
HRT1B	32.4	32.4	37.3	15%
HRT1B_rev	32.7	32.5	37.3	14%
HRT1C	21.7	22.1	21.8	0%
HRT1C_rev	21.6	22.2	21.8	1%
HRT2	38.6	35.7	46.8	21%
HRT2 _rev	38.9	35.9	46.8	20%
HRT20A	78.6	79.4	106.2	35%
HRT20A_rev	78.2	78.6	106.2	36%
HRT20B	41.7	42.2	59.0	42%
HRT20B_rev	42.2	42.5	59.0	40%
HRT23	22.9	24.2	68.9	201%
HRT23_rev	24.5	25.7	68.9	181%
HRT25	31.3	31.7	51.2	63%
HRT25_rev	33.1	31.5	51.2	55%
HRT26A	9.7	9.6	11.6	21%
HRT26A_rev	8.5	9.3	11.6	37%
HRT26B	16.9	17.9	16.4	-3%
HRT26B_rev	15.4	17.5	16.4	6%
HRT27	25.6	24.5	26.2	2%
HRT27_rev	24.9	23.8	26.2	5%
HRT29	60.5	60.4	47.4	-22%
HRT29_rev	61.4	60.6	47.4	-23%
HRT33	63.6	59.2	56.4	-11%
HRT33_rev	65.3	59.9	56.4	-14%
HRT3A	57.5	57.5	63.1	10%
HRT3A_rev	61.3	57.1	63.1	3%
HRT3B	39.6	40.1	44.4	12%
HRT3B_rev	39.1	39.7	44.4	14%
HRT4	32.0	36.9	33.2	4%
HRT4 _rev	28.5	30.4	33.2	16%
HRT41	36.0	31.8	47.6	32%
HRT41_rev	37.2	32.8	47.6	28%
HRT44A	35.2	36.8	67.7	92%
HRT44A_rev	44.2	37.2	67.7	53%
HRT45	28.9	33.3	48.4	68%
HRT45_rev	31.5	28.6	48.4	54%
HRT47	39.6	38.8	45.4	15%
HRT47_rev	41.5	39.6	45.4	9%
HRT5	23.6	23.3	23.5	0%
HRT5 _rev	22.9	23.3	23.5	2%
HRT50	21.0	18.4	27.0	29%
HRT50_rev	21.2	18.5	27.0	28%
HRT57	53.8	45.5	56.7	5%
HRT57_rev	50.4	45.1	56.7	13%
HRT58	29.7	27.3	27.0	-9%

HRT58_rev	30.1	27.6	27.0	-10%
HRT6A	54.0	54.4	49.8	-8%
HRT6A_rev	36.7	35.3	49.8	36%
HRT6C	35.9	37.1	27.8	-23%
HRT6C_rev	18.7	18.2	27.8	48%
HRT8	42.8	43.0	56.3	32%
HRT8 _rev	42.8	43.0	56.3	32%
HRT9	47.8	49.2	50.1	5%
HRT9 _rev	49.3	50.2	50.1	2%
Peninsula Local Service (Mode 2)				
HRT64	81.9	76.6	48.8	-40%
HRT64_rev	78.5	76.3	48.8	-38%
PTRN101	28.4	25.8	26.5	-7%
PTRN101_rev	28.3	25.4	26.5	-6%
PTRN102	28.6	26.9	23.0	-19%
PTRN102_rev	28.4	26.6	23.0	-19%
PTRN103	26.5	26.5	37.2	40%
PTRN103_rev	26.5	26.6	37.2	40%
PTRN104	28.3	28.6	34.0	20%
PTRN104_rev	28.6	28.7	34.0	19%
PTRN105	57.9	56.1	56.1	-3%
PTRN105_rev	59.5	57.7	56.1	-6%
PTRN106	77.0	72.0	74.9	-3%
PTRN106_rev	77.6	71.9	74.9	-3%
PTRN107	82.1	79.4	70.0	-15%
PTRN107_rev	74.1	70.4	70.0	-6%
PTRN109	13.3	11.3	19.5	46%
PTRN109_rev	13.0	11.2	19.5	50%
PTRN110	48.6	45.2	48.8	0%
PTRN110_rev	48.7	45.2	48.8	0%
PTRN111	53.4	53.2	57.6	8%
PTRN111_rev	57.4	56.6	57.6	0%
PTRN112	46.2	46.6	52.2	13%
PTRN112_rev	50.7	50.6	52.2	3%
PTRN114	46.1	42.5	54.4	18%
PTRN114_rev	44.5	41.4	54.4	22%
PTRN115	27.1	25.3	24.5	-10%
PTRN115_rev	26.8	25.2	24.5	-9%
PTRN117B	7.5	7.1	9.5	26%
PTRN117B_rev	8.0	7.4	9.5	19%
PTRN118	23.0	23.1	54.0	135%
PTRN118_rev	22.8	23.0	54.0	137%
PTRN119	13.4	12.7	15.0	12%
PTRN119_rev	13.2	12.6	15.0	14%
PTRN120	16.9	13.6	16.5	-2%
PTRN120_rev	17.3	14.1	16.5	-4%
MAX Service (Mode 9)				
MAX918	35.8	34.5	38.3	7%

MAX919	52.4	43.6	52.6	0%
MAX922	51.0	41.6	61.0	20%
MAX960	39.5	40.7	47.1	19%
MAX961	82.7	80.1	57.4	-31%
MAX961_rev	59.8	73.3	57.4	-4%
MAX962	62.2	57.4	55.1	-12%
MAX962_rev	52.4	56.7	55.1	5%
MAX967N	52.0	54.9	67.6	30%
MAX967S	63.6	55.1	67.6	6%

Comparison of Transit Assignment by Route

At the systems level, the assigned transit boardings from the 2009 Calibration model run compare reasonably well with the observed data. For example, the 2011 ridership data reported by HRT is around 49,750 and the assigned boardings from the model is are 52,500. However, at the individual route level, there is a wide variation on several routes. We recommend some additional calibration of the transit assignment model be done at least for those routes that are in the study area. This should be done in conjunction with fixing the travel times for each route.

Table 5: HDR's 2009 Model Run- Transit Ridership by Route

Route Name	Route Length (mi)	Headways (min)		022312_ModelRun Daily Boardings			Route	2009 Modeled ridership	2010 Observed ridership	Percent difference from observed
		Peak	Off-Peak	Peak	Off-Peak	Total				
Southside Local Service (Mode 1)										
HRT11	2.6	30	30	120	122	242	HRT11	246	406	-39%
HRT11_rev	2.4	30	30	2	2	4				
HRT12	12.3	60	60	156	99	255	HRT12	475	464	2%
HRT12_rev	12.8	60	60	133	87	220				
HRT13A	15.3	60	60	265	96	361	HRT13A	1,127	1,330	-15%
HRT13A_rev	15.4	60	60	198	226	424				
HRT13B	5.7	60	60	76	32	108				
HRT13B_rev	5.8	60	60	98	135	233				
HRT15A	22.2	60	60	551	421	972	HRT15A	4,265	4,040	6%
HRT15A_rev	22.8	60	60	501	812	1,313				
HRT15B	13.1	60	60	430	407	837				
HRT15B_rev	13.5	60	60	405	738	1,143				
HRT18	4.9	60	60	9	12	21	HRT18	40	216	-82%
HRT18_rev	4.9	60	60	4	15	19				
HRT1A	21.5	60	60	269	375	644	HRT1A	2,663	3,352	-21%
HRT1A_rev	21.6	60	60	424	565	988				
HRT1B	9.0	30	0	168	0	168				
HRT1B_rev	9.0	30	0	444	0	444				
HRT1C	5.9	30	0	119	0	119				
HRT1C_rev	6.0	30	0	300	0	300				
HRT2	9.9	30	30	511	860	1,371	HRT2	2,260	1,072	111%
HRT2 _rev	9.8	30	30	520	369	889				
HRT20A	22.5	30	30	1,109	585	1,694	HRT20A	4,737	4,482	6%
HRT20A_rev	22.2	30	30	1,143	945	2,088				
HRT20B	11.9	30	0	478	0	478				
HRT20B_rev	12.0	30	0	477	0	477				
HRT23	7.3	30	30	364	401	765	HRT23	1,848	1,886	-2%
HRT23_rev	7.9	30	30	548	535	1,083				
HRT25	9.4	30	30	86	66	152	HRT25	625	445	41%
HRT25_rev	9.3	30	30	284	189	474				
HRT26A	2.6	60	60	9	12	21	HRT26A	303	207	47%
HRT26A_rev	2.6	60	60	7	5	13				
HRT26B	5.6	60	60	109	82	191				
HRT26B_rev	5.6	60	60	37	42	79				
HRT27	8.8	60	60	46	12	57	HRT27	140	305	-54%
HRT27_rev	8.5	60	60	48	35	82				
HRT29	18.9	60	60	197	121	317	HRT29	643	400	61%
HRT29_rev	18.7	60	60	187	139	326				
HRT310	3.2	15	15	55	138	193	HRT310	193	706	-73%
HRT33	15.9	60	60	5	5	10	HRT33	69	465	-85%
HRT33_rev	16.1	60	60	39	20	59				
HRT36	8.8	60	60	219	160	379	HRT36	1,151	472	144%
HRT36_rev	8.8	60	60	508	264	772				
HRT37	13.3	60	60	13	6	19	HRT37	52	6	760%
HRT37_rev	13.5	60	60	19	14	34				
HRT3A	15.8	60	60	328	329	657	HRT3A	2,145	2,216	-3%
HRT3A_rev	15.5	60	60	177	447	624				
HRT3B	10.7	60	60	293	251	544				
HRT3B_rev	10.6	60	60	100	220	320				
HRT4	10.4	60	60	205	241	446	HRT4	879	282	211%
HRT4 _rev	9.9	60	60	169	264	433				
HRT41	9.5	60	60	94	159	253	HRT41	722	438	65%
HRT41_rev	9.8	60	60	153	315	468				
HRT44A	10.4	60	60	119	42	161	HRT44A	556	500	11%
HRT44A_rev	10.3	60	60	66	97	162				
HRT44B	7.7	60	60	48	46	94				
HRT44B_rev	8.3	60	60	56	83	139				
HRT45	9.5	30	30	379	445	824	HRT45	1,125	1,645	-32%
HRT45_rev	7.6	30	30	172	130	302				
HRT47	11.3	30	30	220	332	552	HRT47	1,058	899	18%
HRT47_rev	11.3	30	30	195	311	506				
HRT5	6.7	60	60	134	179	313	HRT5	450	205	119%
HRT5 _rev	6.7	60	60	31	105	137				
HRT50	5.5	60	60	48	67	114	HRT50	375	275	36%
HRT50_rev	5.5	60	60	76	184	260				

Table 5 Continued

HRT57	12.4	60	60	149	179	328	HRT57	748	417	79%
HRT57_rev	12.5	60	60	152	267	419				
HRT58	7.9	60	60	110	37	147	HRT58	325	258	26%
HRT58_rev	7.9	60	60	98	80	178				
HRT6A	14.0	60	60	177	17	194	HRT6A	729	1,042	-30%
HRT6A_rev	9.8	60	60	123	91	214				
HRT6C	9.1	60	60	146	13	159				
HRT6C_rev	4.9	60	60	92	71	162				
HRT71	9.0	60	60	15	11	27	HRT71	27	116	-77%
HRT71										
HRT72	12.4	60	60	53	44	98	HRT72	98	66	48%
HRT72										
HRT73	8.0	60	60	44	28	72	HRT73	72	62	16%
HRT73										
HRT74	6.4	60	60	38	51	89	HRT74	89	102	-12%
HRT74										
HRT8	11.6	30	30	213	370	583	HRT8	1,690	1,681	0%
HRT8_rev	11.5	30	30	575	531	1,106				
HRT9	13.1	30	30	267	446	713	HRT9	1,943	1,090	78%
HRT9_rev	13.5	30	30	565	665	1,230				
Peninsula Local Service (Mode 2)										
GLSHUTLE	33.6	20	0	45	0	45	GLSHUTLE	52		
GLSHUTLE_rev	34.9	20	0	7	0	7				
HRT64	23.9	60	60	19	2	21	HRT64	21	82	-75%
HRT64_rev	24.0	60	60	0	0	0				
PTR116A	18.7	60	60	98	113	211	PTR116A	211	834	-75%
HRT101	7.5	35	35	282	353	635	HRT101	1,241	1,199	4%
HRT101_rev	7.4	35	35	235	371	606				
HRT102	7.8	60	60	57	46	102	HRT102	225	251	-11%
HRT102_rev	7.8	60	60	56	66	122				
HRT103	8.1	30	30	284	395	679	HRT103	1,364	1,194	14%
HRT103_rev	8.2	30	30	310	375	685				
HRT104	7.9	30	30	276	424	700	HRT104	1,296	982	32%
HRT104_rev	7.8	30	30	249	347	596				
HRT105	15.1	60	60	258	451	709	HRT105	1,477	936	58%
HRT105_rev	15.5	60	60	350	419	768				
HRT106	20.3	60	60	283	375	658	HRT106	1,412	1,601	-12%
HRT106_rev	20.5	60	60	374	380	753				
HRT107	22.7	60	60	374	430	804	HRT107	1,438	1,155	25%
HRT107_rev	20.2	60	60	309	325	634				
HRT109	3.1	60	60	57	65	121	HRT109	198	236	-16%
HRT109_rev	3.1	60	60	33	44	77				
HRT110	13.4	60	60	145	152	297	HRT110	840	738	14%
HRT110_rev	13.4	60	60	288	255	543				
HRT111	15.1	60	60	148	157	304	HRT111	451	667	-32%
HRT111_rev	16.3	60	60	74	72	147				
HRT112	12.5	30	30	401	534	936	HRT112	1,815	2,138	-15%
HRT112_rev	13.5	30	30	426	453	879				
HRT114	12.1	30	30	516	389	905	HRT114	1,560	1,407	11%
HRT114_rev	11.8	30	30	360	295	655				
HRT115	7.4	30	30	435	445	880	HRT115	1,353	653	107%
HRT115_rev	7.3	30	30	228	245	473				
HRT117B	2.3	60	60	27	28	56	HRT117B	109	372	-71%
HRT117B_rev	2.4	60	60	35	19	53				
HRT118	7.4	60	60	17	6	24	HRT118	34	766	-96%
HRT118_rev	7.5	60	60	6	5	11				
HRT119	2.9	40	40	9	9	18	HRT119	64	99	-36%
HRT119_rev	2.9	40	40	22	23	45				
HRT120	3.8	60	60	54	60	114	HRT120	178	241	-26%
HRT120_rev	4.0	60	60	29	34	64				
HRT121X	35.0	90	90	7	1	8	HRT121X	9	54	-84%
HRT121X_rev	33.9	90	90	1	0	1				

Table 5 Continued

Peninsula Local Service (Mode 2)										
GLSHUTLE	33.6	20	0	45	0	45	GLSHUTLE	52		
GLSHUTLE_rev	34.9	20	0	7	0	7				
HRT64	23.9	60	60	19	2	21	HRT64	21	82	-75%
HRT64_rev	24.0	60	60	0	0	0				
PTR116A	18.7	60	60	98	113	211	PTR116A	211	834	-75%
HRT101	7.5	35	35	282	353	635	HRT101	1,241	1,199	4%
HRT101_rev	7.4	35	35	235	371	606				
HRT102	7.8	60	60	57	46	102	HRT102	225	251	-11%
HRT102_rev	7.8	60	60	56	66	122				
HRT103	8.1	30	30	284	395	679	HRT103	1,364	1,194	14%
HRT103_rev	8.2	30	30	310	375	685				
HRT104	7.9	30	30	276	424	700	HRT104	1,296	982	32%
HRT104_rev	7.8	30	30	249	347	596				
HRT105	15.1	60	60	258	451	709	HRT105	1,477	936	58%
HRT105_rev	15.5	60	60	350	419	768				
HRT106	20.3	60	60	283	375	658	HRT106	1,412	1,601	-12%
HRT106_rev	20.5	60	60	374	380	753				
HRT107	22.7	60	60	374	430	804	HRT107	1,438	1,155	25%
HRT107_rev	20.2	60	60	309	325	634				
HRT109	3.1	60	60	57	65	121	HRT109	198	236	-16%
HRT109_rev	3.1	60	60	33	44	77				
HRT110	13.4	60	60	145	152	297	HRT110	840	738	14%
HRT110_rev	13.4	60	60	288	255	543				
HRT111	15.1	60	60	148	157	304	HRT111	451	667	-32%
HRT111_rev	16.3	60	60	74	72	147				
HRT112	12.5	30	30	401	534	936	HRT112	1,815	2,138	-15%
HRT112_rev	13.5	30	30	426	453	879				
HRT114	12.1	30	30	516	389	905	HRT114	1,560	1,407	11%
HRT114_rev	11.8	30	30	360	295	655				
HRT115	7.4	30	30	435	445	880	HRT115	1,353	653	107%
HRT115_rev	7.3	30	30	228	245	473				
HRT117B	2.3	60	60	27	28	56	HRT117B	109	372	-71%
HRT117B_rev	2.4	60	60	35	19	53				
HRT118	7.4	60	60	17	6	24	HRT118	34	766	-96%
HRT118_rev	7.5	60	60	6	5	11				
HRT119	2.9	40	40	9	9	18	HRT119	64	99	-36%
HRT119_rev	2.9	40	40	22	23	45				
HRT120	3.8	60	60	54	60	114	HRT120	178	241	-26%
HRT120_rev	4.0	60	60	29	34	64				
HRT121X	35.0	90	90	7	1	8	HRT121X	9	54	-84%
HRT121X_rev	33.9	90	90	1	0	1				
Trolley Service (Mode 3)										
ATLTR_rev	2.8	15	15	32	61	93	ATLTR_rev	167		
ATLTRO	2.8	15	15	30	43	74				
LYNTRO	8.7	60	60	29	21	51	LYNTRO	63		
LYNTRO_rev	8.0	60	60	6	6	12				
RUDTRO	3.7	15	15	73	75	148	RUDTRO	333		
RUDTRO_rev	3.7	15	15	97	88	185				
SEATRO	3.4	20	20	23	13	36	SEATRO	50		
SEATRO_rev	3.4	20	20	10	5	14				
Ferry Service (Mode 4)										
HRTEFE	0.9	30	30	103	97	199	HRTEFE	406		
HRTEFW	0.9	30	30	69	138	207				
NET Service (Mode 5)										
HRT17	2.2	6	9	169	181	350	HRT17	1,565	1,090	43%
HRT17_rev	2.2	6	9	5	34	39				

Table 5 Continued

Williamsburg Transit Local Service (Mode 6)										
HRT7	4.7	60	60	0	363	363	HRT7	726	1	54406%
HRT7_rev	3.6	60	60	0	363	363				
WATGRA	12.0	60	60	80	60	141	WATGRA	362		
WATGRA_rev	11.6	60	60	137	84	221				
WATGRN	2.9	30	30	58	42	100	WATGRN	197		
WATGRN_rev	2.9	30	30	61	37	97				
WATBLUE	6.2	60	60	137	81	219	WATBLUE	419		
WATBLUE_rev	6.3	60	60	106	94	200				
WATORG	9.3	60	60	40	40	80	WATORG	240		
WATORG_rev	9.1	60	60	95	66	160				
WATPURP1	8.9	60	60	168	119	286	WATPURP1	527		
WATPURP1_rev	8.9	60	60	119	122	241				
WATPURP2	10.9	60	60	30	26	56	WATPURP2	133		
WATPURP2_rev	10.8	60	60	46	31	77				
WATRED	8.9	60	60	125	81	206	WATRED	315		
WATRED_rev	6.4	60	60	59	50	109				
WATSURRY	6.4	120	0	166	121	287	WATSURRY	430		
WATSURRY_rev	6.4	120	0	73	71	143				
WATTAN	7.3	60	60	26	14	40	WATTAN	88		
WATTAN_rev	7.3	60	60	26	21	47				
WATTrol	3.4	30	30	71	46	117	WATTrol	257		
WATTrol_rev	3.4	30	30	88	52	140				
Fringe Transit (Mode 7)										
HRT17N	2.2	6	0	474	0	474	HRT17N	See HRT17	See HRT17	
HRT17S	2.2	6	0	702	0	702				
Fringe Shuttles (Mode 8)										
HRTBOA	1.2	5.6	0	2,894	0	2,894	HRTBOA	2,894		
HRTDHS	0.3	9	0	567	0	567	HRTDHS	567		
HRTSSA	0.9	22.5	0	46	0	46	HRTSSA	46		
MAX Service (Mode 9)										
MAX918	17.8	90	0	16	0	16	MAX918	16	34	-52%
MAX919	20.1	33	0	131	0	131	MAX919	131	155	-15%
MAX922	21.0	36	0	96	0	96	MAX922	96	152	-37%
MAX960	23.4	60	60	15	17	31	MAX960	31	241	-87%
MAX961	24.6	30	60	307	28	335	MAX961	491	639	-23%
MAX961_rev	24.2	30	60	137	19	156				
MAX962	28.4	30	0	31	0	31	MAX962	54	100	-46%
MAX962_rev	27.7	30	0	23	0	23				
MAX963	12.9	60	60	29	87	115	MAX963	115	20	466%
MAX967N	34.6	30	0	5	0	5	MAX967N	6	154	-96%
MAX967S	35.8	60	0	1	0	1				
PTR113X	16.9	60	60	58	33	92	PTR113X	105	10	945%
PTR113X_rev	15.2	60	60	8	5	13				
Total				**32,650**	**27,394**	**60,044**		**52498*** **	**49754*** **	
							***Sum only includes boardings where both modeled and observed num			

Table 6

Observed Routes That Could Not Be Matched

Route	Boardings
34	0
63	0
76	38
90	726
300	166
350	0
403	24
405	60
406	2
409	16
412	13
414	72
415	24
424	6
427	1
430	62
432	2
1000000	203
1000001	16
Total	**1,433**

Table 7: Percent Difference of Travel Time and Ridership (Observed vs. Modeled)

Route Name	2012 Schedule Time vs. 2009 Model	Percent difference from Observed
South Peninsula Local Service (Mode 1)		
HRT11	35%	-39%
HRT11_rev	41%	
HRT15A	36%	6%
HRT15A_rev	33%	
HRT15B	15%	
HRT15B_rev	16%	
HRT18	57%	-82%
HRT18_rev	61%	
HRT20A	35%	6%
HRT20A_rev	36%	
HRT20B	42%	
HRT20B_rev	40%	
HRT23	201%	-2%
HRT23_rev	181%	
HRT25	63%	41%
HRT25_rev	55%	

HRT26A	21%	47%
HRT26A_rev	37%	
HRT26B	-3%	
HRT26B_rev	6%	
HRT41	32%	65%
HRT41_rev	28%	
HRT44A	92%	11%
HRT44A_rev	53%	
HRT45	68%	-32%
HRT45_rev	54%	
HRT6A	-8%	-30%
HRT6A_rev	36%	
HRT6C	-23%	
HRT6C_rev	48%	
HRT8	32%	0%
HRT8 _rev	32%	
Peninsula Local Service (Mode 2)		
HRT64	-40%	-75%
HRT64_rev	-38%	
PTRN103	40%	14%
PTRN103_rev	40%	
PTRN109	46%	-16%
PTRN109_rev	50%	
PTRN118	135%	-96%
PTRN118_rev	137%	
MAX Service (Mode 9)		
MAX961	-31%	-23%
MAX961_rev	-4%	
MAX967N	30%	-96%
MAX967S	6%	

Major Findings

- The level of transit service coded in the model (peak and off-peak headways) compare very well with actual service with some minor exceptions. The exceptions can be corrected.

- The bus travel times computed in the model vary significantly when compared to schedules times. It is recommended that the travel time on each route be scaled up or down to match the scheduled travel times and the model be re-calibrated.

- The assigned transit boardings in the model match reasonable well with the observed ridership data at the systems level. However, at the route level, there is a wide variation. It is recommended that the transit assignment model be re-calibrated after correcting the computed travel times.

Appendix K-4

THE VIRGINIA BEACH TRANSIT EXTENSION STUDY (VBTES)

CALIBRATION and VALIDATION OF RIDERSHIP MODEL

Prepared by:

HDR | ONE COMPANY *Many Solutions*®

Prepared for:

HRT Hampton Roads Transit

May 2013

EXECUTIVE SUMMARY

In June 2011, the Federal Transit Administration (FTA) recommended that Hampton Roads Transit (HRT) prepare revised opening-year patronage forecasts for the TIDE light rail system in Norfolk as part of the Virginia Beach Transit Extension Study (VBTES). The recommendation stemmed from observations by HRT that conditions in Hampton Roads – population, employment, and the transit system – had changed substantially since the opening-year forecast had been prepared for the Tide's full funding grant application in 2008 (Norfolk EIS model). The purpose of the new opening year forecast was to evaluate how well the model would respond to the changed conditions and to test if it was accurately representing actual travel behavior in the corridor so that it could be used as an effective tool for the VBTES.

In response to FTA's request, HRT and its contractor, HDR Engineering, updated the demographic and transit network input data to the travel model and recomputed the opening year ridership using the Norfolk EIS model. The revised ridership on the TIDE line was approximately in the same range as the 2008 estimate. Further analysis of the model indicated some additional calibration and validation of the transit component was necessary.

As model calibration and testing was taking place using the Norfolk EIS model, a new regional travel demand forecasting model was being developed for the Virginia Department of Transportation (VDOT). A draft version of new model (VDOT model) became available in early 2012. Initial evaluation of the VDOT model indicated the transit component was validated primarily at the systems level. In order to apply the model to the TIDE corridor, a more focused calibration and validation to the study area was needed.

As part of the calibration effort, two major travel surveys were conducted—one of the bus system prior to the opening of the TIDE, and one on the TIDE eight months after it opened for revenue service. Following the initial evaluation of the new transit model several parameters in the model were adjusted based on the findings from the two travel surveys. These adjustments included updating centroid connector distances, revising maximum walk access distances to transit centers for buses and rail, lowering transfer penalties, adjusting fares, updating park-and-ride connections and bus run times. Also, a new rail mode was added to the model to facilitate the calibration of the fixed guideway system.

The final calibrated model generated about 4,590 weekday boardings which are very close to the average observed boardings of 4,600 during the period of August 2011 to March 2012. The calibrated model also produced a more accurate distribution of ridership among the eleven rail stations.

Introduction / Background

This report has been prepared as part of the ridership forecasting activities for the Virginia Beach Transit Extension Study (VBTES). Initial forecast prepared for the study were based on work completed as part of the Norfolk Light Rail Transit Draft/Final Environmental Impact Statement (Norfolk EIS Model). The ridership forecasts prepared using the Norfolk EIS model from 2007-2008 indicated that approximately 2,900 riders per day would use the system during the system's opening year. After a year of operation, the Norfolk Light Rail system, called the TIDE, has actually been carrying in excess of 4,600 riders per day. Recognizing this severe underestimation of rail ridership forecasts, Federal Transit Administration (FTA) questioned the readiness of the EIS model to produce reliable ridership forecasts for the VBTES corridor.

In June 2011, the FTA recommended that Hampton Roads Transit (HRT) prepare revised opening-year forecasts for the TIDE line. The recommendation stemmed from observations made by HDR (HRT's Consultant) and HRT that conditions in Norfolk – population, employment, and the transit system – had changed substantially since the opening-year forecast had been made in 2008. In response to FTA's request, HDR updated the demographic and transit network input data to the travel model and recomputed the opening year ridership. The revised ridership on the TIDE line was approximately in the same range as the 2008 estimate. Further analysis of the model indicated additional calibration and validation of the model were necessary. In the meantime, HRT began conducting a large scale, system wide Origin-Destination travel survey on their bus system. The survey was conducted and completed in the last week of July 2011. A month later, the TIDE went into service and was an instant success. While the modeling discussions were taking place between HRT and FTA, a new travel demand model was being developed by AECOM consultants under contract to the Virginia Department of Transportation (VDOT).

In March 2012, a draft version of the new model[14] became available for use in planning studies. This new model would be used by the local MPO (Hampton Roads Transportation Planning Organization, HRTPO) as well as HRT for all their future planning studies. HDR was directed to use the new travel model to conduct ridership forecasting analysis for their VBTES study. Initial application and evaluation of VDOT's new regional travel model indicated the transit component of that model was validated primarily at the systems level. As a result, the new model also underestimated rail ridership significantly. In order to apply the new model to the TIDE corridor, HDR concluded a more focused model calibration and validation to the study area was needed.

In April 2012, approximately 8 months after the TIDE began operation HRT conducted another major Origin-Destination survey on the rail line and collected detailed information pertaining to the travel characteristics of the TIDE customers. HDR used the 2011 Bus survey results and the 2012 Rail survey results to conduct a thorough calibration and validation of the transit component of the new model.

The primary purpose of this report is to describe the methodology used in the model calibration and validation process and present the results.

[14] According to VDOT, the new model is still undergoing some minor revisions (mostly on the highway side). As such, a final version has not been completed. Also, a complete documentation of the new model is not yet available. Their current schedule indicates the model documentation will be finalized in January 2013 at which time it will be made available to HRT and FTA.

VDOT Hampton Road Regional Travel Demand Model

The new VDOT travel demand forecasting model is based on the traditional four-step planning process of trip generation, trip distribution, mode choice, and assignment. At the time of this writing, a complete documentation of the model was not yet available from VDOT for public release. When the model documentation becomes available, this report will be updated to include a detailed discussion of all the model components. As with any other four-step travel model, the transit portion of the travel demand in this model set is captured in the mode choice and transit assignment models. The transit model includes all of Peninsula and South Peninsula local service, Trolley service, Ferry service, The NET service, Williamsburg Transit local service, Fringe Shuttles, and Max express service.

Our calibration and validation efforts were targeted primarily at the last two (Mode Choice and Transit Assignment) components of the model. The 2011 bus survey and 2012 rail survey provided the fundamental data needed for calibration and validation.

Based on the scripts embedded in the mode choice and assignment models, the basic structure of the current VDOT's mode choice and assignment models can be deduced. The following paragraphs present a brief description of these two model components.

The Current VDOT's Mode Choice Model

The purpose of VDOT's mode choice model is to estimate the overall transit and highway demand in the region. It is basically a Nested Logit model which divides the total trip demand into Auto trips, Transit trips and Fringe parking trips. The auto trips are further divided into Drive Alone mode, Shared Ride mode (with 2 people), and Shared ride mode (with 3 or more people). The transit trips are further divided into Walk Access transit trips and Drive Access (park and Ride) transit trips. The Fringe Parking trips are further divided into those who park at the Fringe parking facility and walk to their destinations, those who park at the Fringe parking facility and take transit to their final destinations, and those who park at the Fringe parking facility and take Shuttle buses to reach their final destinations. **Figure 1** shows the structure of the current mode choice model.

As part of the original calibration, several sets of modal constants (relative to Auto Drive Alone mode) were estimated for all modes in the mode choice model. **Table 1** shows the values of these constants. In **Table 2,** these constants are expressed in equivalent in-vehicle travel times (IVTT). In general, the values of these constants are in the same range as in most regional travel models in the country.

Figure 1: Structure of VDOT's Current Mode Choice Model

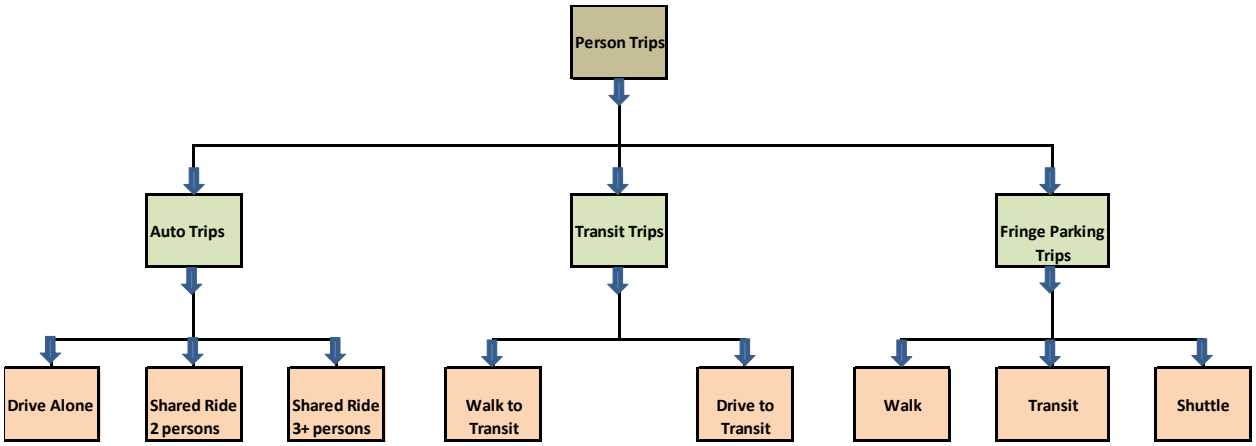


Table 1: Modal Constants in VDOT's Model

Trip Purpose	Drive alone	ShareRide 2 persons	ShareRide 3+ persons	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	-15	-6.3	-6.4	7.4	-15
Peak Home-Based Work trips 1+car	0	-2.7	-4.05	-0.6	-7.87
Peak- Home-Based Other trips 0- car	-3.3	-0.5	-0.65	-0.8	-15
Peak Home-Based Other trips 1+car	0	-0.3	-0.69	-4.3	-6.2
Peak Non-Home-Based trips	0	-0.87	-1.51	-6.35	0
Off-Peak- Home-Based Work trips 0- car	-15	-4.1	-4.2	6	-15
Off-Peak Home-Based Work trips 1+car	0	-2.35	-3.6	-2.7	-7
Off-Peak- Home-Based Other trips 0- car	-2.4	-0.75	-1.3	-0.08	-15
Off-Peak Home-Based Other trips 1+car	0	-0.45	-0.97	-4.7	-15
Off-Peak Non-Home-Based trips	0	-0.71	-1.185	-6.2	0

Source: VDOT's model Scripts

Table 2: Modal Constants in Equivalent In-vehicle Travel Time

Trip Purpose	Drive alone	ShareRide 2 persons	ShareRide 3+ persons	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	300	126	128	-148	300
Peak Home-Based Work trips 1+car	0	54	81	12	157
Peak- Home-Based Other trips 0- car	66	10	13	16	300
Peak Home-Based Other trips 1+car	0	6	13.8	86	124
Peak Non-Home-Based trips	0	17.4	30.2	127	0
Off-Peak- Home-Based Work trips 0- car	300	82	84	-120	300
Off-Peak Home-Based Work trips 1+car	0	47	72	54	140
Off-Peak- Home-Based Other trips 0- car	48	15	26	1.6	300
Off-Peak Home-Based Other trips 1+car	0	9	19.4	94	300
Off-Peak Non-Home-Based trips	0	14.2	23.7	124	0

VDOT's Current Transit Assignment Model

The transit assignment model in VDOT's regional model assigns the transit trips estimated by the mode choice model to different transit paths and estimates transit boardings on each bus route. This model uses an "All or Nothing" algorithm in which transit trips from any given origin zone to destination zone are assigned to the best transit path identified by the model. The path building parameters embedded in the assignment model are shown in **Table 3.**

Table 3: Transit Path Building Parameters in VDOT's Model

Parameter	Walk to Transit	Drive to Transit
Access Modes	Mode 16: Zonal walk Mode 12: Transfer	Mode 12: Transfer Mode 15: Drive
Line Haul modes	Mode 1: Southside local Mode 2: Peninsula Local Mode 3: Trolley Mode 4: Ferry Mode 5: NET Mode 6: WATA Mode 9: Express bus	Mode 1: Southside local Mode 2: Peninsula Local Mode 3: Trolley Mode 4: Ferry Mode 5: NET Mode 6: WATA Mode 9: Express bus
First Wait	½ headway (HW) if HW <15 min or 7.5 + ¼ (HW-15) if HW>15 min	½ headway (HW) if HW <15 min or 7.5 + ¼ (HW-15) if HW>15 min
Second Wait	½ headway	½ headway
Wait time factor	2.5	2.5
Transfer Penalty	3 min	3 min
Transfer time factor	2.5	2.5
Run time factor for path Favoring (by line haul mode)	Modes 1-10 : 1.0	Modes 1-10 : 1.0

The Need For Model Calibration

When the new model was developed for VDOT, the primary focus was on the highway side. As a result, the calibration of the transit model was performed only at the systems level. For the 2009 base year, the new VDOT model estimated about 40,000 linked transit trips and around 55,000 transit boardings on the transit entire system. These numbers match well to the actual ridership data. However, the model did not perform well in the TIDE corridor. Initial evaluation indicated several bus routes under performed in the TIDE corridor. When the TIDE was modeled as a bus mode[15], it generated only a daily ridership of 1,750 boardings. It became evident that the model needed further calibration in the TIDE corridor before it could be used as a reliable forecasting tool for the VBTES study. This finding is consistent with the discussion HDR had with AECOM consultants.

Calibration and Validation Methodology

The overall approach used in the calibration and validation of the transit component of the new model consists of two parts:

[15] The current VDOT's model does not have an exclusive rail mode. So, the TIDE rail was coded as a bus mode.

In part one, the transit assignment model was updated to ensure the model built and chose transit paths that were very similar to what passengers actually made per the bus survey and assigned the trips to the appropriate transit routes. To achieve this, the 2011 system wide Bus Survey data were converted to trip matrices and assigned to the transit network in the VDOT model. The results were carefully analyzed and compared to the survey data. Several fixes were proposed to rectify any network building issues that surfaced from such comparison. These fixes are discussed in Section 6. After the fixes were incorporated, the assignment model was rerun and further adjustments were made when necessary to ensure the model replicated the actual travel paths with reasonable accuracy (up to 90 percent).

In part two, the modal constants in the mode choice model were adjusted such that it replicated the linked transit trips (from the survey) in various travel markets with reasonable accuracy. The technical procedures required in part one and two were implemented in an organized 10-step process as described in Section 6. After these adjustments were made, the entire four steps of the updated VDOT model were rerun using the 2011 base year input data. The calibration/validation was done first for the bus system using the 2011 bus survey and repeated for the rail mode using the 2012 rail survey.

Data Used

In 2011 and 2012, HRT expended significant effort in collecting travel pattern data on most of their system with a specific emphasis on the TIDE corridor, the VBTES corridor, and other key areas of Norfolk and Virginia Beach. Significant information on travel patterns as discussed below was mined from these two surveys which improved the forecasting ability of the travel model.

Bus Survey (July 2011) and Key travel markets

A system-wide Origin-Destination bus survey was conducted in July 2011. That survey included HRT's local bus routes, Max Express routes, Newport News shipyard routes, Suffolk routes, HRT ferry route, Downtown Norfolk routes, and Virginia Beach Wave routes. The survey was developed in order to gain additional insights into riders' travel, demographic, and attitudinal characteristics before HRT's new "The Tide" light rail system opened on August 19, 2011. The survey was specifically designed to provide guidance on improvements to the overall HRT transit system as part of updates to the Transit Development Plan. A total of 7,523 responses were received from a weekday total of 52,618 HRT riders on the surveyed routes. Statistics on trip purpose, transfer activity, access mode, riders' attitudes, and socio-economic metrics were summarized for each service type as well as system-wide. These statistics indicate about 57 percent of the trips made by HRT users are home based trips. Around 82 percent of the passengers use walk mode to access transit. Nearly 40 percent of the users make at least one transfer to complete their trip. An interesting finding from the bus survey is nearly 60 percent of the bus users use transit because that is their only option. About 45 percent of the surveyed people stated they use HRT system 6 or 7 days a week on a regular basis. A detailed analysis of the survey data is presented in a separate report which is included in Appendix A.

The TIDE Survey (April 2012) and key travel markets

In April 2012, about 8 months after the TIDE line opened, another Origin-Destination survey was conducted on the rail line. The survey was developed in order to gain additional insights into riders' travel, demographic, and attitudinal characteristics. Two separate questionnaires were

developed to survey riders aboard the TIDE and HRT Ferry. While many questions were similar, certain questions were tailored to the different rider characteristics and the desire to ask specialized questions to each mode. A sampling plan was developed to provide a reasonable level of confidence (approximately 90%). The TIDE and Ferry systems were surveyed on Thursday, April 19th, Friday, April 20th, and Saturday, April 21st, 2012. Surveyors rode aboard each train or ferry trip and approached all passengers with a survey questionnaire. A total of 3,336 surveys were returned on these three days. The total number of responses received on Thursday was 1,398 (1,257 TIDE; 141 Ferry), on Friday, it was 1,034 (911 TIDE; 123 Ferry), and on Saturday, it was 904 (878 TIDE; 26 Ferry). It should be noted this was a survey of rail and ferry trips only. The bus trips were not surveyed after TIDE opened.

A detailed examination of the survey results indicate about 34 percent of TIDE riders are either traveling from home to work or returning home from work. Approximately 25 percent of riders are either traveling to or returning from the universities and colleges. Home based trips for recreational, medical, personal business, and other trips constituted another 12 percent. The Survey shows 36 percent of TIDE riders are residents of Norfolk and 19 percent are from Virginia Beach. Nearly 40 percent of those surveyed did not reveal their residential locations. According to the survey, 37 percent walked to access the rail, 22 percent transferred from buses, 31 percent drove to a park-and-ride facility, 4 percent rode their bicycles, and 2.5 percent got dropped off. A large percentage (between 40 to 50 percent) of TIDE riders ride the rail 5 days a week or more, indicating a more regular trip. The survey also indicates nearly 80 percent of the TIDE passengers pay discounted fares. About 18 percent of the riders do not have a working vehicle at home, and close to 10 percent indicated transit was their only option to make the trip. From the survey, it appears that TIDE passengers are extremely satisfied with the service. Nearly 100 percent indicated they would recommend the TIDE to others.

Calibration Steps

The transit model calibration and validation was completed by making maximum use of newly acquired travel survey data to identify key travel markets, travel patterns, and transit access characteristics. That information was used to develop access coding conventions, test the validity of model's path building parameters, set targets for mode choice model calibration, and adjust modal constants and path parameters in the model to simulate the current ridership pattern. (For a description of the travel surveys undertaken, see Appendix A and B)

For the purpose of this report, the following terms are defined.

Pre-Opening: This term refers to the time frame just before the TIDE service began operation.

Post-Opening: This term refers to the time frame approximately one year after the TIDE service began operation. By this time, the rail ridership had some what stabilized and ranged in the order of 4,500 to 5,000 trips a day.

The calibration/validation was performed in a systematic way using the following steps.

Step 1: Replicate base year model run to ensure it is consistent with VDOT's version and conduct an initial evaluation of the transit component of the new model.

Step 2: Update the transit network and other model inputs from 2009 to 2011.

Step 3: Develop **"First Cut"** ridership results for the TIDE line from the new model and assess results.

Step 4: Develop a survey-based transit trip table using the results of the Pre-Opening bus survey conducted in July 2011.

Step 5: Test assign the survey-based trip table to Pre-Opening network. Analyze results and propose fixes.

Step 6: Establish targets (linked trips by trip purpose, transit access, time of day, and auto ownership) for Mode Choice from the bus survey.

Step 7: Apply fixes, and run model with 2011 inputs and calibrate the mode choice model constants to match targets.

Step 8: Develop a survey-based transit trip table using Post-Opening rail survey and establish targets (linked rail trips by trip purpose, transit access, time of day, and auto ownership) for Mode Choice calibration.

Step 9: Test assign the rail survey-based trip table to Post-Opening transit network. Analyze results and propose fixes.

Step 10: Apply fixes, run the model with the TIDE line. Check mode split and distribution of trips in the TIDE study area. Apply fixes if necessary. Adjust modal constant for rail mode iteratively until assigned boardings in the model are reasonably close to observed rail ridership.

STEP 1: Base Year Model Replication and Initial Evaluation of the New Model

The transit and highway components of VDOT's new travel model were calibrated and validated to 2009 conditions. HRT and its contractor were able to replicate the base year model results successfully. This confirmed that all the input data, scripts, and other model inputs used by HRT were consistent with VDOT. The mode choice and transit assignment results of the 2009 model run are shown in **Table 4** below.

Table 4: Mode Choice and Assignment Results of VDOT's model

Mode Choice	2009 Calibration Run
Home Based Work	
Drive Alone	730,554
Shared Ride 2	78,827
Shared Ride 3	30,604
Walk Transit	20,792
Drive Transit	585
Fringe Park- Walk	1,938
Fringe Park-Transit	871
Fringe Park- Shuttle	2,860
Total	**867,030**
Home Based Other	
Drive Alone	1,314,815
Shared Ride 2	1,044,897
Shared Ride 3	681,522
Walk Transit	14,924
Drive Transit	154
Total	**3,056,312**
Non Home Based	
Drive Alone	1,737,111
Shared Ride 2	898,737
Shared Ride 3	555,689
Walk Transit	3,737
Total	**3,195,275**
Transit assignment results	
Peak Drive trips	292
Peak walk trips	26,788
Peak Fringe parking shuttle trips	1,060
Peak Fringe parking transit trips	1,119
Off-peak drive trips	621
Off-peak walk trips	25,653
Total	***55,533***

As seen from the assignment results in **Table 4**, the 2009 VDOT calibration run simulated approximately 55,500 daily boardings compared to HRT's 53,000 observed boardings. However, on some routes, there was a large variation between the assigned ridership and the observed ridership (between 20 and 40 percent). After replicating the model results, the accuracy of the 2009 transit network representation was verified by reviewing the routing of each bus, stop locations, headways, and transfer connections. The review found most routes were coded properly with a few exceptions that were subsequently corrected. However, bus travel times computed by the model varied significantly on several routes when compared to the scheduled travel times. These routes were subsequently constrained to match scheduled times.

STEP 2: Updating 2009 Transit Network to 2011 Pre-Opening Conditions

Step 2 of the calibration process involved updating the 2009 transit network to reflect the 2011 network conditions just before the TIDE began operation. The physical routing of the bus routes as coded in the 2009 networks were compared with 2011 bus schedules. Several minor fixes were made to a number of routes to reflect the service changes HRT implemented between November 28, 2010 and August 7, 2011. Most of these changes were necessary to provide better intermodal connections with the TIDE. The service updates are shown in Appendix C. The demographic data were updated to the 2010 Census data. Since no significant changes occurred on the highway system between 2009 and 2011, the 2009 highway network was used as a proxy for a new 2011 highway network.

STEP 3: Preliminary Opening Year TIDE Ridership Results

To establish a baseline to gauge the performance of the model, The TIDE line was coded in the *un-validated 2011 model*. The mode choice model embedded in the new VDOT travel model did not have an exclusive rail mode in the network. Therefore, for the purposes of this test, the TIDE service was coded as a *local bus mode*. However, the headways and travel times on the service were coded to match the current rail service. The preliminary results from a un-validated 2011 model run with this update simulated 1,750 boardings a day in the opening year (see **Table 5**).

Table 5: Preliminary Opening Year Ridership on the TIDE from VDOT's Model

STATION NAME	OBSERVED BOARDINGS (Aug 11 thru March 12)	MODELED BOARDINGS (TIDE coded as a local bus mode)
EVMC	600	215
Freemason	145	118
Monticello	470	144
MacArthur	700	103
Civic Plaza	375	182
Harbor Park (P)	135	182
NSU	375	143
Ballentine (P)	310	177
Ingleside	70	19
Military Hwy (P)	425	211
Newtown Road (P)	1,010	252
Total	***4,615***	***1,746***

As shown in **Table 5,** the actual observed ridership on the TIDE was, on the average, about 4,600 boardings a day in early 2012. The VDOT's travel model was severely underestimating the TIDE ridership by about 62 percent.

This underestimation may have been due to a number of reasons including issues related to distribution of trips in the study area, mode shares to downtown trips, and treating light rail as a local bus mode. But more importantly, the transit component of the VDOT model was calibrated at the systems level to a condition that *pre-dated* the TIDE service. The travel attributes of the light rail system were not used in the estimation of the mode choice model. Besides, the focus of VDOT's model improvement was mainly on the highway side. As such, the transit

component did not undergo any major updates primarily in the area of transit walk and drive access parameters. Going forward, the next steps in the model enhancement process were to use the 2011 Bus Onboard Survey and 2012 TIDE Rail Survey to calibrate and validate the mode choice and assignment modules of the model.

STEP 4: Development of Survey-Based Transit Trip Table Using the 2011 Bus (Pre-Opening) Survey Data

The 2011 Bus Survey data were organized, checked for format errors and corrected when necessary and factored to match boardings by route. These factored survey data were organized by production and attraction zones, time period, trip purpose, and mode for transformation into the trip table matrices. Appendix A contains a detailed description of the bus survey and some major findings on the existing travel markets and trip making characteristics. **Table 6** presents a summary of the expanded survey trips.

Table 6: Summary of Expanded 2011 Bus Survey Trips (Linked Trips)

(Pre-Opening Condition)

Period	Purpose	Auto Avail.	MODE		Grand Total
			Drive	Walk	
Peak	Home Based Other trips	No	60	2,631	2,691
		Yes	69	1,695	1,763
	Home Based Work trips	No	79	5,262	5,342
		Yes	437	3,841	4,278
	Non-Home Based trips	No		1,074	1,074
		Yes	30	458	488
Off-peak	Home Based Other trips	No	16	3,292	3,308
		Yes	30	2,628	2,658
	Home Based Work trips	No	3	3,703	3,706
		Yes	157	3,357	3,513
	Non-Home Based trips	No	39	933	972
		Yes	44	627	671
Grand Total			**963**	**29,500**	**30,463***

*These are linked trips. They do not include the intermediate transfers made to complete the entire trip. Also, they do not include the 16 HRT routes and all of Williamsburg routes that were not surveyed.

STEP 5: Assignment of Survey-Based Trip Table to Pre-Opening Transit Network

In order to determine if the transit network representation, network coding conventions, path building parameters, and representation of transit access in the model were reasonably accurate and realistic, the survey-based trip table was assigned to the Pre-Opening transit network. The assignment results indicated 29 percent of the survey trips were unassignable as shown in **Table 7.**

After analyzing the assignment results in greater detail, several issues were uncovered. They pertained to:

- Issue 1: Coding conventions used for transit access links for local bus mode;
- Issue 2: Distance coded on Centroid connector links;
- Issue 3: Walk access links coded for transit centers; and
- Issue 4: Missing park and ride nodes.

Table 7: Bus Survey Trip Table Assignment (Pre-Opening Condition)

	Total	Unassigned	Assigned	% Unassigned
Peak -Walk Access trips	14,328	4,333	9,996	30%
Peak –Drive Access trips	960	311	648	32%
Off-Peak -Walk Access trips	14,286	3,746	10,540	26%
Off-Peak –Drive Access trips	390	159	231	41%
Total	**29,964**	**8,549**	**21,414**	**29%**
Total Assigned Boardings			**36,919**	

Network and Path Issues in the Current Model

Issue 1: Access Distances

As shown in **Figure 2**, the bus survey results indicate that more than 90 percent of the trips involved a walk access mode. So, the first parameter to analyze was to ensure proper representation of walk access connections in the model. The model has a hard limit of 0.5 miles for walk access or egress to transit. However, the survey responses for walk distances show that 90 percent of passengers walk 5 blocks (approximately ½ mile) or less (**Figure 3**). This means that almost 10 percent of walk access survey trips would be unassigned because of walk access distance. This issue is further compounded by what was found in the survey regarding bicycle access trips. About 2.8 percent of trips in the survey indicated that they biked to the bus (**Figure 4**). Since the model does not have a separate bike access mode, these are added to the walk access trip table. Since only 20 percent of these bike access trips report a distance of a ½ mile or less, that leaves 80 percent that would be unassignable. That 80 percent translates to about 2 percent of the total survey trips.

Figure 3: Transit Mode of Access – 2011 Bus Survey Results

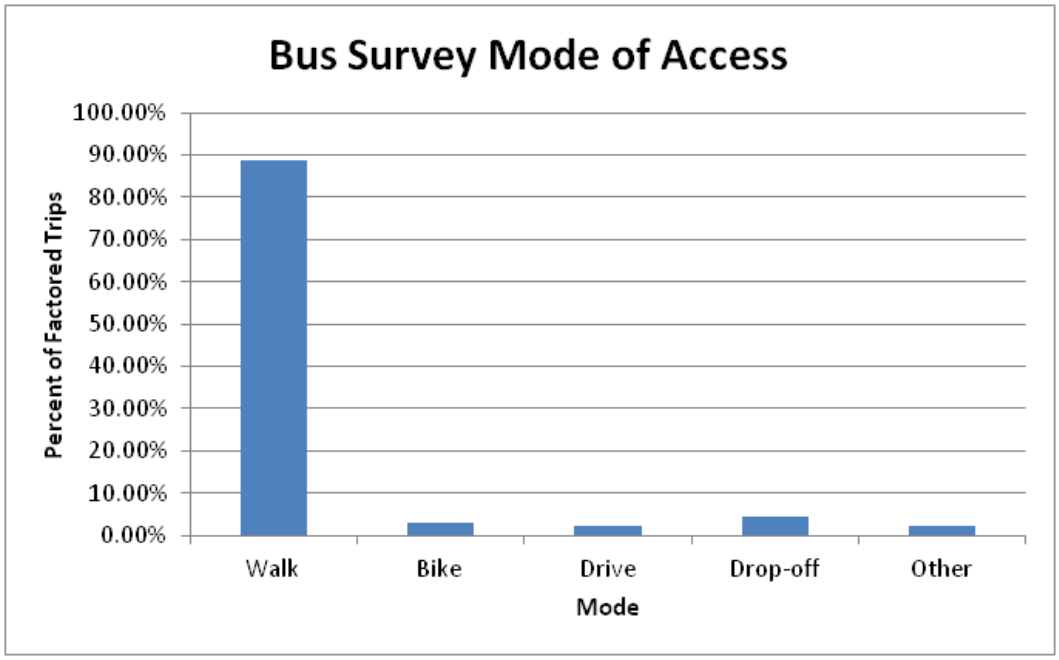


Figure 4: Distribution of Walk Distances to Bus

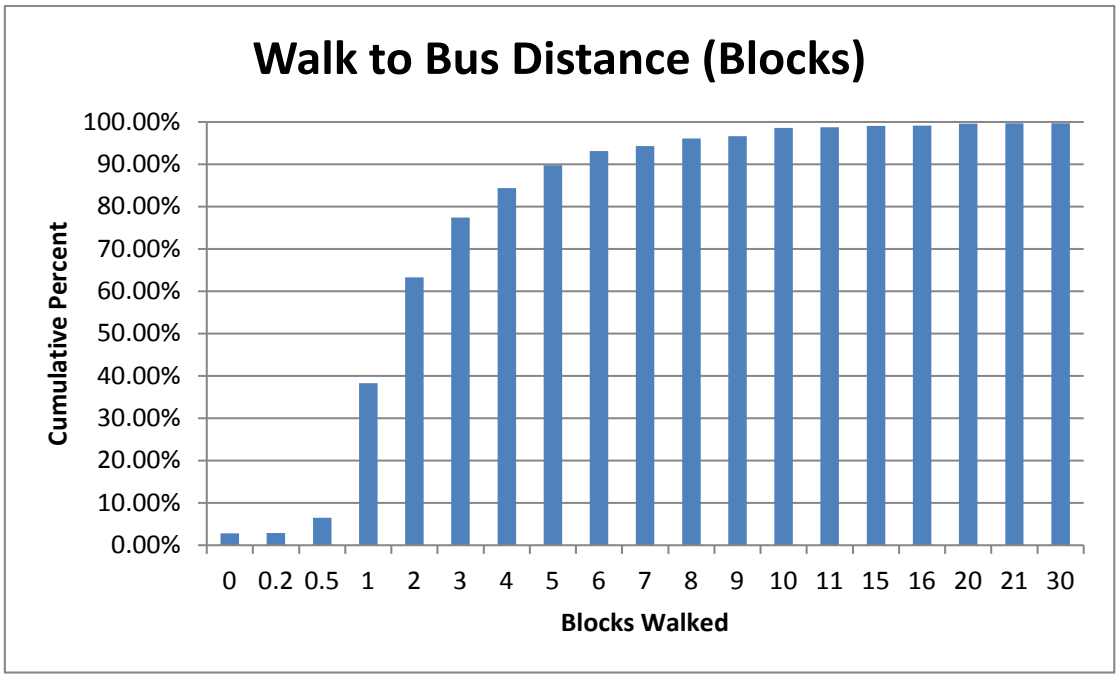
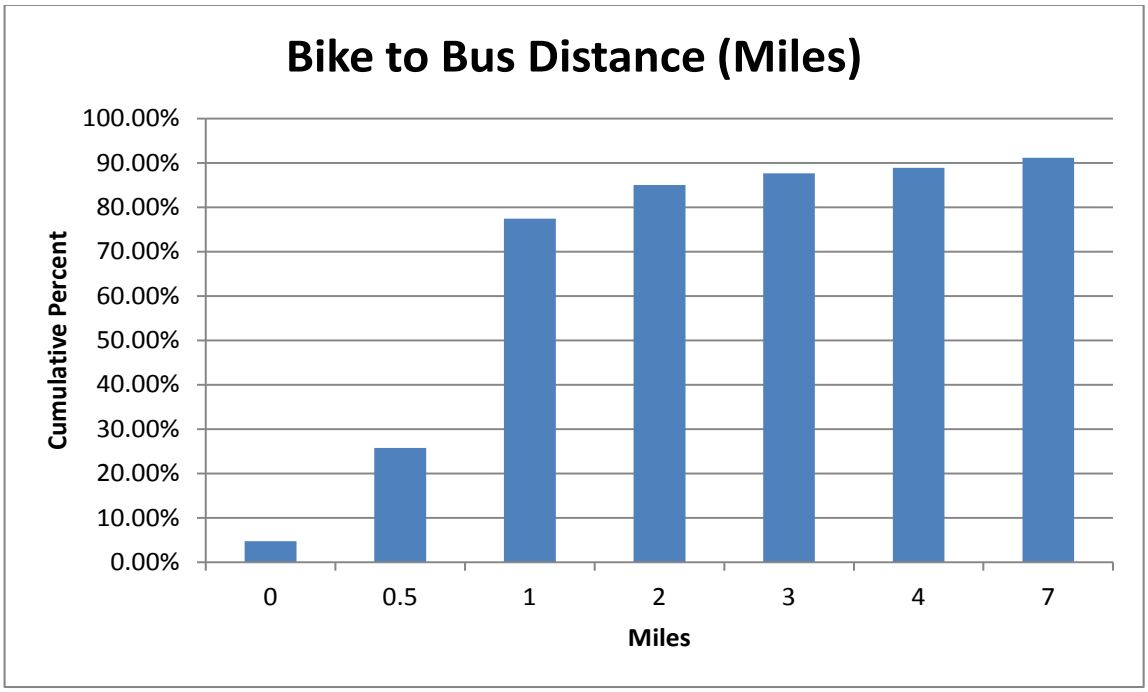


Figure 5: Distribution of Bike Access Distance to Transit



Issue 2: Centroid Connectors

Another walk access issue was discovered in the model related to centroid connectors. When examining the unassigned trips in detail, it was found that some zones were not allowing walk trips in or out of the zone. The zones had centroid connectors that connected the highway network at or near bus stops. However, those centroid connectors were longer than 0.5 miles and thus walking was prohibited in the model.

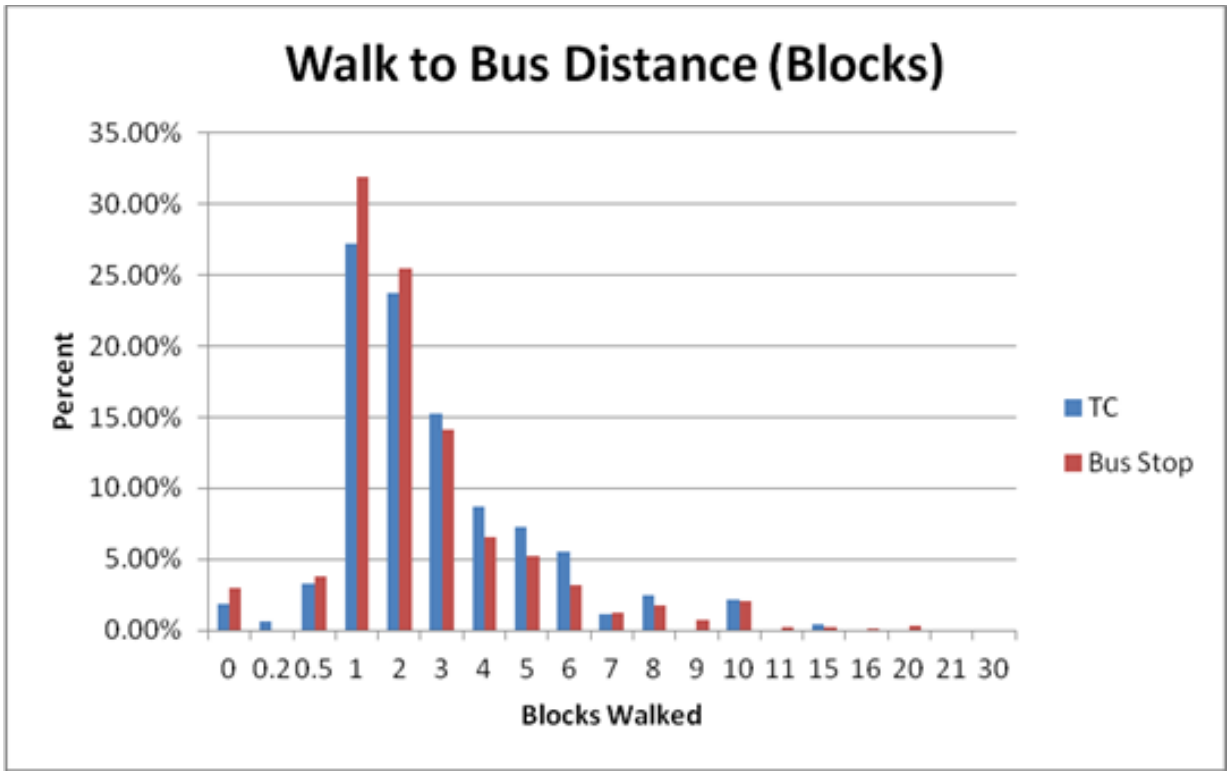
Issue 3: Walk Access Links to Transit centers

Additionally, when examining walk access distances, it was observed that the walk distances to transit centers and other transit facilities were longer than the walk distances to other bus stops (**Figure 5).**

Issue 4: Drive Access Links

The drive access trips also had path issues during assignment. There are two main causes that were identified. First, not all park-and-ride lots were coded into the model. Second, some park and ride lots and many drop-off trips used locations that were not formal park and ride locations.

Figure 6: Walk Distances for Transit Center versus Bus Stops



Implemented Fixes

Set MaxWalk for Local Buses

Based on the survey finding, the MaxWalk parameter for local buses was set to 0.50 miles to account for the majority of local bus users.

Capped Distance on Centroid Connectors

The first proposed model modification was to limit the walk length of long centroid connectors. A key was added to the model that controls the walking distance of centroid connectors. The transit skimming and assignment procedures were changed to use the minimum of the actual connector length and the maximum length key. By setting the key to 0.45 miles, most zones with adjacent bus service became walk accessible. This reduced the unassigned survey trips from 29 percent to 20 percent.

Increased Walk Distance to Transit Facilities

Based on the findings from the bus survey (**Figure 5**), the maximum walk distance was increased from 0.5 miles to 0.75 miles for the following transit facilities and transfer centers. This adjusted for the additional attractiveness of these improved facilities with multiple route choices.

Transit Facilities	
20th St/Seaboard Ave	Patrick Henry Mall
26th St/Jefferson Ave	Peninsula Town Center
Cedar Grove	Robert Hall Blvd Shopping Center
County St/Court St	Rudee Inlet
Ft. Norfolk/EVMC	Settlers Landing/Armistead Ave
Hampton Transit Center	Suffolk Bus Plaza
Little Creek Blvd/Evelyn T Butts Ave	TIDE Stations
Military Circle Mall	Tidewater Community College
Navy Exchange Mall	Victory Crossing
NET Center	Washington Ave/26th St
Newport News Transit Center	

Added Missing Park & Ride Locations

The VDOT's travel model contained the following park-and-ride locations: Silver Leaf, Greenbrier Mall, Indian River, Magnolia, Ferry. However, two park and ride lots were missing. This problem was corrected by adding the following locations: Hampton Transfer Center, US 60 & Old Courthouse Way. This allowed park and ride access on the Peninsula. This correction brought down the total unassigned trips from 20 percent to 19 percent. It also reduced unassigned drive access trips.

Re-checked Bus Route Coding

All routes were reviewed for the final time to verify that the correct routes had stops at the transfer locations. Transfer links at every one of the transit centers shown above were checked and corrected, if necessary, to reflect proper transfer connections and transfer times. This allowed the appropriate transfer activity to occur in the model process.

Fare Representation

In the current VDOT model, full fare was coded on all transit modes. The current adult fare for HRT's bus and rail system is $1.50. There are several fare types as shown in **Table 8** that offer various types of discounts to Seniors, Disabled and Youth passengers. There were also several discounts for bulk purchases. The bus survey results indicated nearly 48 percent of the passengers paid discounted fares. The rail survey showed about 85 percent of passengers paid discounted fares. About 40 percent of rail riders used GoPass365 fare on an average weekday. It should also be noted that several employers in the study area subsidize their employees' transit fares almost 100 percent. As a result of all these dynamics and or the purpose of modeling, HRT instructed HDR to use $0.91[16] as average fare for both the bus and rail modes.

[16] The average fare was estimated using an annual revenue of $14,542,518 and annual ridership of 16,017,811 associated with the bus and ferry modes.

Table 8: HRT's Bus and Rail Fares

Fare Type	Fare
Adult	$1.50
Youth (<18 years)	$1.00
Seniors	$0.75
Child	Free
1-Day GoPass	$3.50
Five 1-Day GoPass	$16.50
1-Day GoPass (S,D,Y)	$1.75
Five 1-Day GoPass (S,D,Y)	$8.75
7-Day GoPass	$17.00
30-Day GoPass	$50.00
30-Day GoPass (S,D,Y)	$35.00
GoPass 365	See footnote[17]

Note: S –Senior, D – Disabled, Y- Youth

After all of the above fixes were applied to the model inputs, the survey trip table was again assigned to the model. This improved the unassignable trips from 19 percent to 15 percent as shown in **Table 9.**

Table 9: Final Survey Trip Table Assignment

	Total	Unassigned	Assigned	% Unassigned
Peak -Walk Access trips	14,328	2,292	12,037	16%
Peak –Drive Access trips	960	58	901	6%
Off-Peak -Walk Access trips	14,286	1,994	12,292	14%
Off-Peak –Drive Access trips	390	58	332	15%
Total	**29,964**	**4,402**	**25,562**	**15%**
		Total Assigned Boardings	**43,141**	

STEP 6: Establish Trip Targets for Mode Choice Calibration

The new regional model includes all bus routes in the region. However, the 2011 bus survey (Pre-Opening) did not include all bus routes. Sixteen HRT routes as well as all of Williamsburg routes were excluded in the survey. In order to develop proper targets for mode choice model calibration, the trips extracted from the survey needed to be factored up to account for non-surveyed routes. This was done by dividing the actual system wide boardings on all routes by the actual boardings on the surveyed routes and estimating the adjustment factor. The computed adjustment factor was 1.326.

Table 10 presents the targets set for mode choice model calibration. As shown, the calibration target for Walk Access market was 39,390 daily linked trips and for Drive Access market was 1,330 daily linked trips. These targets included only the transit trips made by walk access and

[17] For students and employees of educational institutions, GoPass 365 costs $6.00 per year. For other employees, the cost depends on the number of employees in the company (ranging between $25 and $250 per year).

drive access modes. For calibration purposes, targets for those trips that use the Fringe Parking facilities were required. Those targets were computed separately from AECOM's 2005 Fringe Parking survey. **Table 11** shows the targets set for Fringe Parking trips.

Table 10: Target Trips for Mode Choice Model Calibration

Trip Purpose	Walk Access trips	Drive Access trips
Peak- Home-Based Work trips 0- car	7,040	0
Peak Home-Based Work trips 1+car	5,130	695
Peak- Home-Based Other trips 0- car	3,540	0
Peak Home-Based Other trips 1+car	2,250	220
Peak Non-Home-Based trips	2,050	
Off-Peak- Home-Based Work trips 0- car	4,930	0
Off-Peak Home-Based Work trips 1+car	4,450	210
Off-Peak- Home-Based Other trips 0- car	4,410	0
Off-Peak Home-Based Other trips 1+car	3,480	205
Off-Peak Non-Home-Based trips	2,100	
Total	**39,390**	**1,330**

Table 11: Targets for Fringe Parking Trips for Mode Choice Model Calibration

	Walk	NET	Shuttle Bus
Daily trips at Fringe Parking Facility	**1,640**	**900**	**2,375**

STEP 7: Apply all Fixes from 2011 Bus Survey Analysis and run 2011 Base Year Model with base year Inputs (Pre-Opening condition)

All the network fixes discussed above were incorporated in the base year model and a Pre-Opening run was conducted using the base year demographic and land use data provided by HRTPO. The results from the mode choice model and assignment model were summarized and analyzed thoroughly. The results indicated the average transfer rate for each passenger was around 1.20. However, the survey results indicated the average transfer rate was around 1.50. In order to increase the transfer rate in the model to match the survey results, the transfer penalty embedded in the model was modified.

The original penalty in the model was 3 minutes. Applying a weighting factor of 2.5 (see Table 3), the transfer penalty equaled 7.5 equivalent in-vehicle minutes in the transit skimming and assignment process. In the mode choice component, the model used a weighting factor of 3.5 which equaled to 10.5 equivalent in-vehicle minutes in mode choice.

To increase the transfer rate, the original transfer penalty was changed from 3 minutes to 2 minutes. The weighting factors were not altered. This increased the transfer rate in the model

from 1.20 to 1.30. The mode choice model was rerun, and the linked trips by access mode were summarized and compared to the calibration targets shown in Table 10. The zero-car and one-car targets were added together for each purpose. The next step in the calibration process was to adjust the modal constants for each transit access mode until it produced linked transit trips close to the calibration targets. The zero-car and one-car modal constants were adjusted together until the combined target was reached. This avoided an issue with unrealistic values for the zero-car constants. Since the model does not contain an automated calibration routine, this exercise had to be conducted iteratively by running the model dozens of times.

The final calibration constants estimated for the mode choice model are shown in **Table 12.** These constants expressed in equivalent in-vehicle **(IVTT)** time are shown in **Table 13.**

Table 12: Values of Mode Choice Constants after Calibration

Trip Purpose	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	-1.70	-99.00
Peak Home-Based Work trips 1+car	-1.70	-5.84
Peak- Home-Based Other trips 0- car	-4.30	-99.00
Peak Home-Based Other trips 1+car	-4.30	-7.18
Peak Non-Home-Based trips	-6.40	0.00
Off-Peak- Home-Based Work trips 0- car	-1.85	-99.00
Off-Peak Home-Based Work trips 1+car	-1.85	-6.50
Off-Peak- Home-Based Other trips 0- car	-4.90	-99.00
Off-Peak Home-Based Other trips 1+car	-4.90	-8.40
Off-Peak Non-Home-Based trips	-7.83	0.00

Table 13: Values of Mode Choice Constants in Equivalent IVTT Minutes

Trip Purpose	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	34.0	1980
Peak Home-Based Work trips 1+car	34.0	116.8
Peak- Home-Based Other trips 0- car	86.0	1980
Peak Home-Based Other trips 1+car	86.0	143.6
Peak Non-Home-Based trips	128.0	0.0
Off-Peak- Home-Based Work trips 0- car	37.0	1980
Off-Peak Home-Based Work trips 1+car	37.0	130.0
Off-Peak- Home-Based Other trips 0- car	98.0	1980
Off-Peak Home-Based Other trips 1+car	98.0	168.0
Off-Peak Non-Home-Based trips	156.6	0.0

The calibrated model for the Pre-Opening network scenario produced about 49,200 system wide boardings per typical weekday. Table 14 shows a summary of the calibrated model results from the Pre-Opening run.

Table 14: Pre-Opening Model Results after Calibration

Model Statistic	Base Year: 2011 Pre-Opening network	Targets to match
System wide linked transit trips		
Drive access	1,340	1,330
Walk access	39,780	39,390
Fringe Walk (not part of transit)	1,680	1,640
Fringe transit	950	900
Fringe shuttle	2,450	2,375
Total linked trips	46,200	45,640
Boarding Summary		
Local Bus (rtes 1-121)	45,820	46,200
The NET & Shuttles	3,570	3,460
All Max Routes	953	1,490
Max Rte 960	200	240
TIDE LRT	Not applicable	Not applicable
Daily boardings (whole system)	49,200	52,360

Validation (Pre-Opening Condition)

In the travel demand modeling practice, an error tolerance of 10 to 15 percent is generally considered as acceptable in the calibration process. On this scale, the application of the calibrated model to simulate the base year 2011 boardings produced acceptable results. The boarding assignment results generated by the model matches well with observed data for several important bus routes as shown in Table 15. For example, the modeled boardings for 12 bus routes in the study area were within 3 percent of the observed ridership. On Max routes, the modeled boardings were about 35 percent lower than the observed boardings. However, on Max route 960, which runs in the TIDE corridor and is more relevant to the VBTES study, the modeled boardings were only 16 percent lower than the observed boardings.

Figure 6 shows the correlation between the modeled boardings versus observed boardings. In general, the assignment model replicated the observed boardings with an acceptable level of precision. The R Square value was 0.85.

A comparison of modeled boardings versus observed boarding for all the local routes in the South Side as well as the Peninsula is shown in Table 16. As seen in this table, the modeled boardings for a major portion of the system were within 3 percent of the observed boardings.

Table 15: Pre-Opening Model Assignment

Bus Routes	2011 Pre-TIDE Observed Boardings	Base Year Pre-Opening Model
Local Route 13	1,330	795
Local Route 15	4,040	3,900
Local Route 18	215	180
Local Route 2	1,180	1,450
Local Route 20A	4,480	5,380
Local Route 23	1,885	1,575
Local Route 25	445	700
Local Route 27	305	460
Local Route 45	1,645	1,550
Local Route 6A	1,040	980
Local Route 8	1,680	1,620
Local Route 9	1,090	1,120
NET and Shuttle	**3,460**	**3,570**
Total Local	**22,795**	**23,280**
Max Route 918	35	10
Max Route 919	155	155
Max Route 922	150	250
Max Route 960	240	200
Max Route 961	640	285
Max Route 962	100	15
Max Route 967	150	30
Total Max	**1,470**	**945**

Figure 7: Modeled Boardings versus Observed Boardings

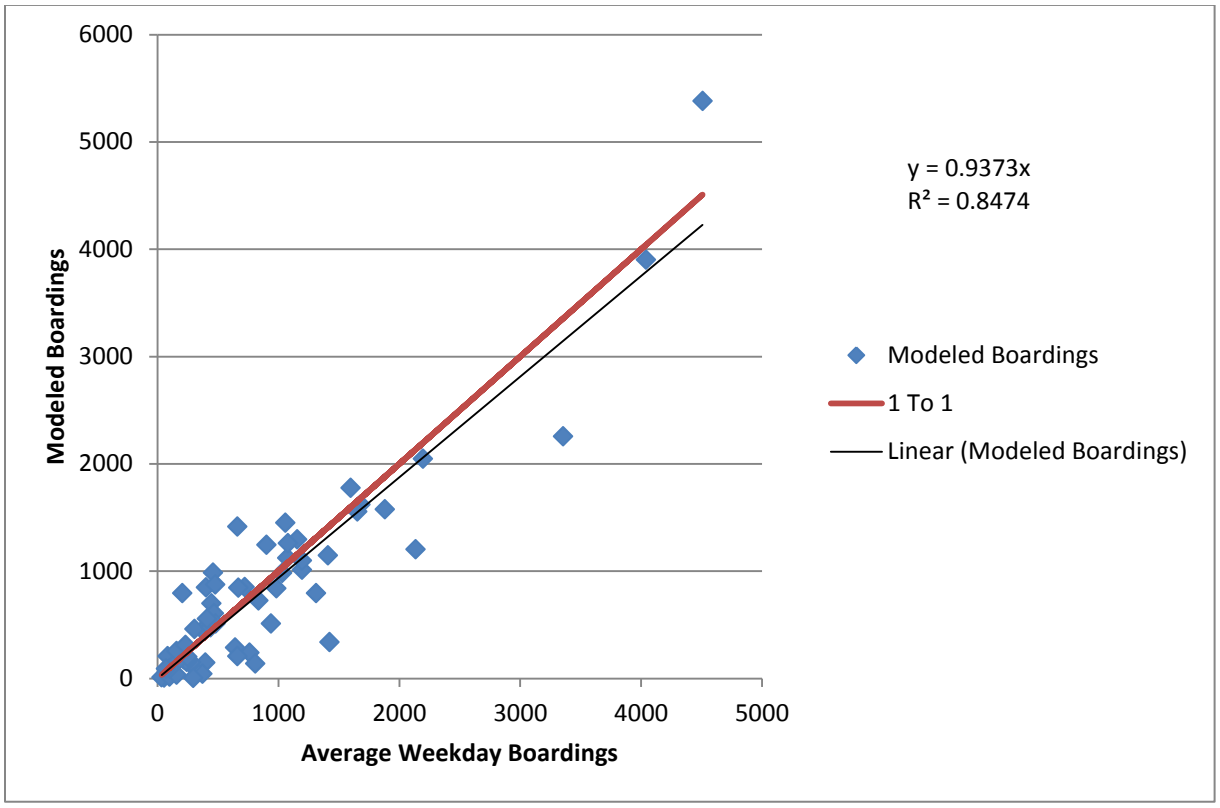


Table 16: Modeled Boardings versus Observed Boardings (Pre-Opening Scenario)

Route	Average Weekday Observed Boardings	Modeled Boardings
Route 1 Granby Street	3,360	2,260
Route 2 Hampton Boulevard	1,060	1,450
Route 3 Chesapeake Boulevard	2,200	2,050
Route 4 Church Street	280	130
Route 5 Willoughby	210	190
Route 6 South Norfolk/Robert Hall	1,030	980
Route 8 Tidewater Drive	1,680	1,620
Route 9 Sewells Point Road	1,070	1,120
Route 11 Colonial Avenue	400	140
Route 12 Indian River Road	460	990
Route 13 Campostella	1,310	790
Route 14 Battlefield Boulevard	370	450
Route 15 Crosstown	4,040	3,900
Route 18 Ballentine Boulevard	220	180
Route 20 Virginia Beach Boulevard	4,510	5,380
Route 23 Princess Anne Road	1,880	1,580

Route	Average Weekday Observed Boardings	Modeled Boardings
Route 25 Newtown Road	450	700
Route 26 Lynnhaven Mall	210	790
Route 27 Northampton	310	460
Route 29 Great Neck/Lynnhaven	400	850
Route 33 General Booth Boulevard	470	600
Route 36 Holland Road	480	870
Route 41 Cradock	440	470
Route 43 Parkview	90	100
Route 44 Midtown	480	510
Route 45 Portsmouth Boulevard	1,650	1,550
Route 47 High Street	900	1,240
Route 50 Academy Park	280	150
Route 57 Deep Creek Boulevard	410	560
Route 64 Smithfield	80	200
Route 101 Kecoughtan	1,200	1,010
Route 102 Queen Street	250	170
Route 103 Shell Road	1,200	1,100
Route 104 Newsome Park	980	840
Route 105 Briarfield Road	940	510
Route 106 Warwick Boulevard	1,600	1,770
Route 107 Denbigh Boulevard	1,160	1,300
Route 109 Buckroe	240	150
Route 110 Thomas Nelson	720	850
Route 111 Riverside	670	840
Route 112 Jefferson Avenue	2,140	1,200
Route 114 Weaver Road	1,410	1,150
Route 115 Fox Hill Road	660	1,410
Route 116 Mall Hall	840	720
Route 117 Phoebus	370	40
Route 118 Magruder Boulevard	760	240
Route 119 Oyster point	100	60
Route 120 Mallory	240	160
Route 121 Williamsburg	60	10
Route 918 Silverleaf/NSA	30	10
Route 919 Silverleaf/Naval Station	160	150
Route 922 Greenbrier	160	250
Route 960 MAX	250	200
Route 961 Crossroads	640	290
Route 962 MAX	100	20

Route	Average Weekday Observed Boardings	Modeled Boardings
Route 967 MAX	160	30
Route 74 Lake Kennedy/South Suffolk	100	90
Ferry	810	140
Route 17 The Net	1,080	1,260
Total *	**49,760**	**48,230**

* Includes only Southside local service, Peninsula local service and Max service.

STEP 8: Develop LRT Trip Table from Post-Opening TIDE Survey

A trip table was generated from the TIDE survey. Valid surveys[18] were factored to match boardings by time period. These factored surveys were organized by production and attraction zones, period, trip purpose, and access mode for transformation into trip table matrices. Table 15 presents a summary of the surveyed rail trips by time of day and trip purpose. There were approximately 4,560 rail trips in the expanded survey. A complete documentation of the TIDE survey is shown in Appendix B.

Table 17: Summary of LRT Trip Table from the Rail Survey

Period	Purpose	Auto Availability	Walk	Drive	Grand Total
Peak	HBW	No	20	30	50
		Yes	480	670	1,150
	HBO	No	30	10	40
		Yes	180	280	460
	NHB		310		310
Off-Peak	HBW	No	20	10	30
		Yes	450	270	720
	HBO	No	40	40	80
		Yes	620	520	1140
	NHB		580		580
Grand Total			**2,740**	**1,820**	**4,560**

STEP 9: Test Assign Survey Trip Table and Analyze Results

Since the new model did not have an exclusive rail mode, the TIDE line was coded as a local bus in the network and a Post-Opening scenario was created. The travel times on the bus were coded to match the current running time of the TIDE. The peak and off-peak headways were coded at 10 minutes and 15 minutes respectively. When the survey trip table was assigned to the Post-Opening network, 14 percent of the survey trips were not assignable. Zone to zone

[18] Valid surveys are those which contained error-free responses to all questions relevant for modeling purposes.

interchanges without a valid transit path in the model network resulted in these unassigned survey trips. One cause of this could be problems with the geo-coding of the survey origin or destination addresses. Another cause could be the actual transit paths that are used by passengers are considered invalid by the model for reasons that may be related to path building parameters (restrictions) and to transit access coding conventions used for the rail line.

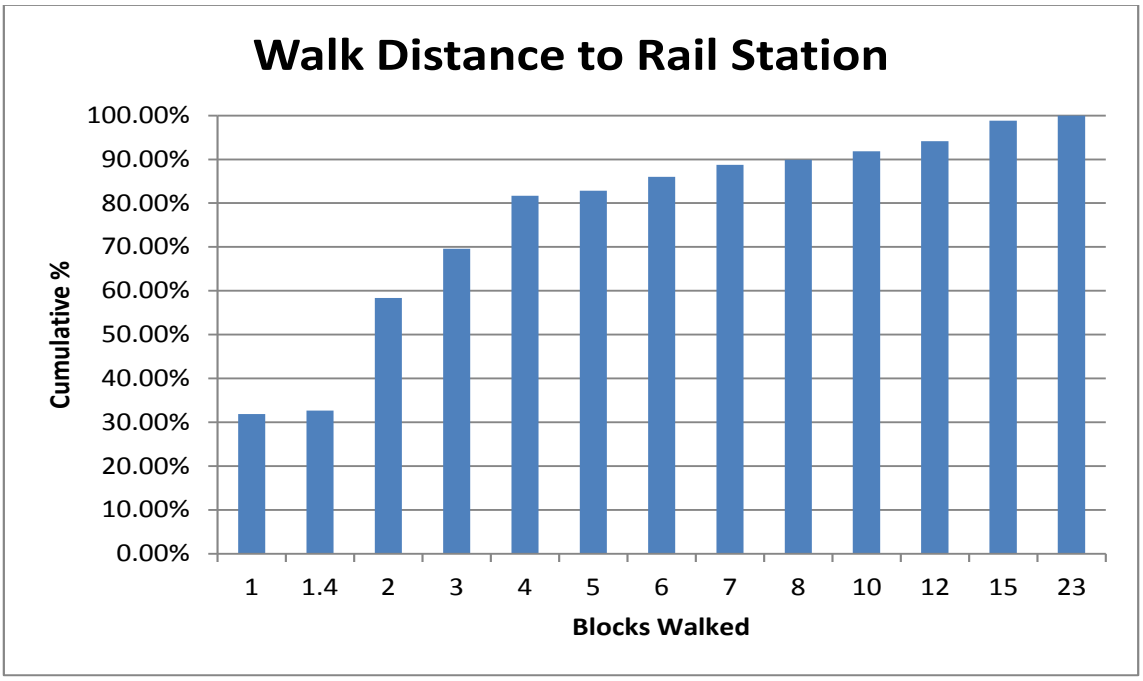
The assignment results also indicated another 20 percent of the trips were assigned to bus only paths. For these trips, the model's assignment procedures determined that using a bus would be the best path from the origin to the destination even though the rider actually rode the TIDE. This could be because the model was informed to treat the TIDE line as another bus mode; and therefore, the extra attractiveness associated with the rail service such as reliability, safety, network connectivity, and ride quality was never figured in the path selection process. It is also possible there were some errors in the survey responses regarding the stated origins and destinations for these trips. Unfortunately, it is not possible to specifically identify these types of errors.

One of the ways to inform the model that LRT paths are more attractive than the bus paths (for a given origin to destination) was by weighting the running time on the LRT mode in the path selection process. This was done in the Step 10.

Examination of Walk Distances to TIDE

Based on the survey results, it was noted that on the average riders of TIDE walked longer to access the rail than the bus riders. Shown in Figure 7 is the cumulative distribution of walk access distance to rail from the survey. As seen, more than 90 percent of the passengers walked 12 blocks or less to access the rail station. This finding suggests that the MaxWalk parameter for LRT stations need to be set at least to the same value as for the Transit Centers.

Figure 8: Distribution of Walking Distance to TIDE



McArthur Station Access

The assignment results also indicated the assigned ridership at the MacArthur Station was very low compared to the actual boardings. In the model, the zones containing MacArthur Shopping Center (TAZ 2 north of the station) and Waterside Festival Marketplace Plaza (TAZ 907 south of the station) do not have convenient links to MacArthur Station.

STEP 10: Apply Fixes, Run Model with TIDE, Adjust Mode Choice Constant for Rail to Replicate Observed Ridership.

Implemented Fixes

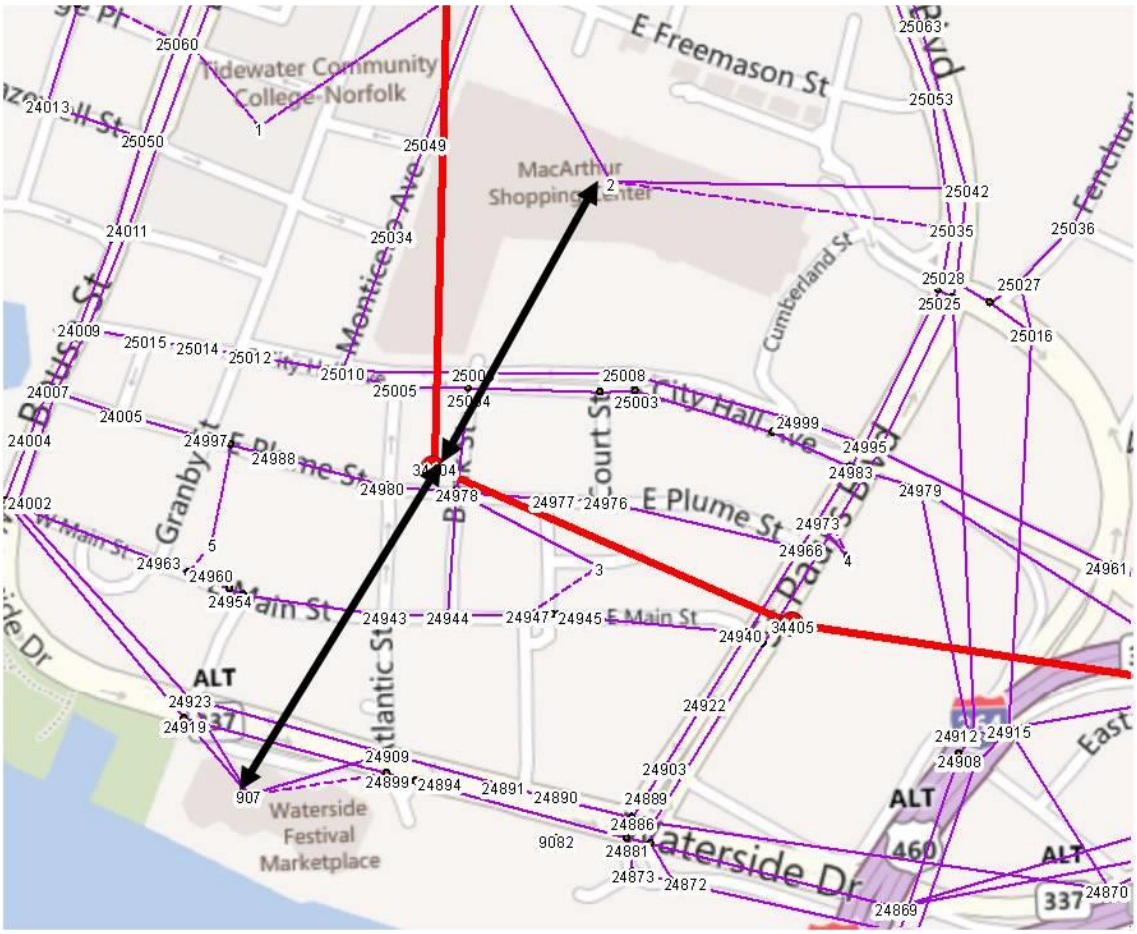
Set Walk Distance to Rail Stations Same as Transit Centers

LRT stations were added to the list of stations and transit centers so that they also allow the extended maximum walk to 0.75 miles.

MacArthur Station Connections

To correct the MacArthur Station access link issues, new links were added to the Transit Only links file. The new links are shown in **Figure 8.**

Figure 9: Location of New Access Links



After adding the connections at MacArthur the station boarding results improved in that some of the drive access trips got shifted from Harbor Park to EVMC and some of the walk trips got shifted to MacArthur from the surrounding stations. However, the overall ridership did not change.

Introduce LRT mode and add run time factor to render LRT paths more attractive

A new LRT mode was introduced in the network and a weight factor of 0.9 was applied to LRT runtime in the path building algorithm. This would essentially make any transit paths involving the LRT mode 10 percent more attractive in terms of travel time when compared to other available modes for a given origin to destination zone.

The results of this assignment run (**Table 18**) include all the fixes discussed above. This assignment showed an improvement from 14 percent unassignable to 10 percent unassignable survey trips. However, the trips assigned to bus only mode instead of LRT mode decreased only by 2 percent, from 20 percent to 18 percent. It is not clear how many of the survey trips were incorrectly geo-coded in terms of the origins and destinations that could have caused some trips to be assigned to bus only paths.

Table 18: Survey Trip Table Assignment with all Network Fixes

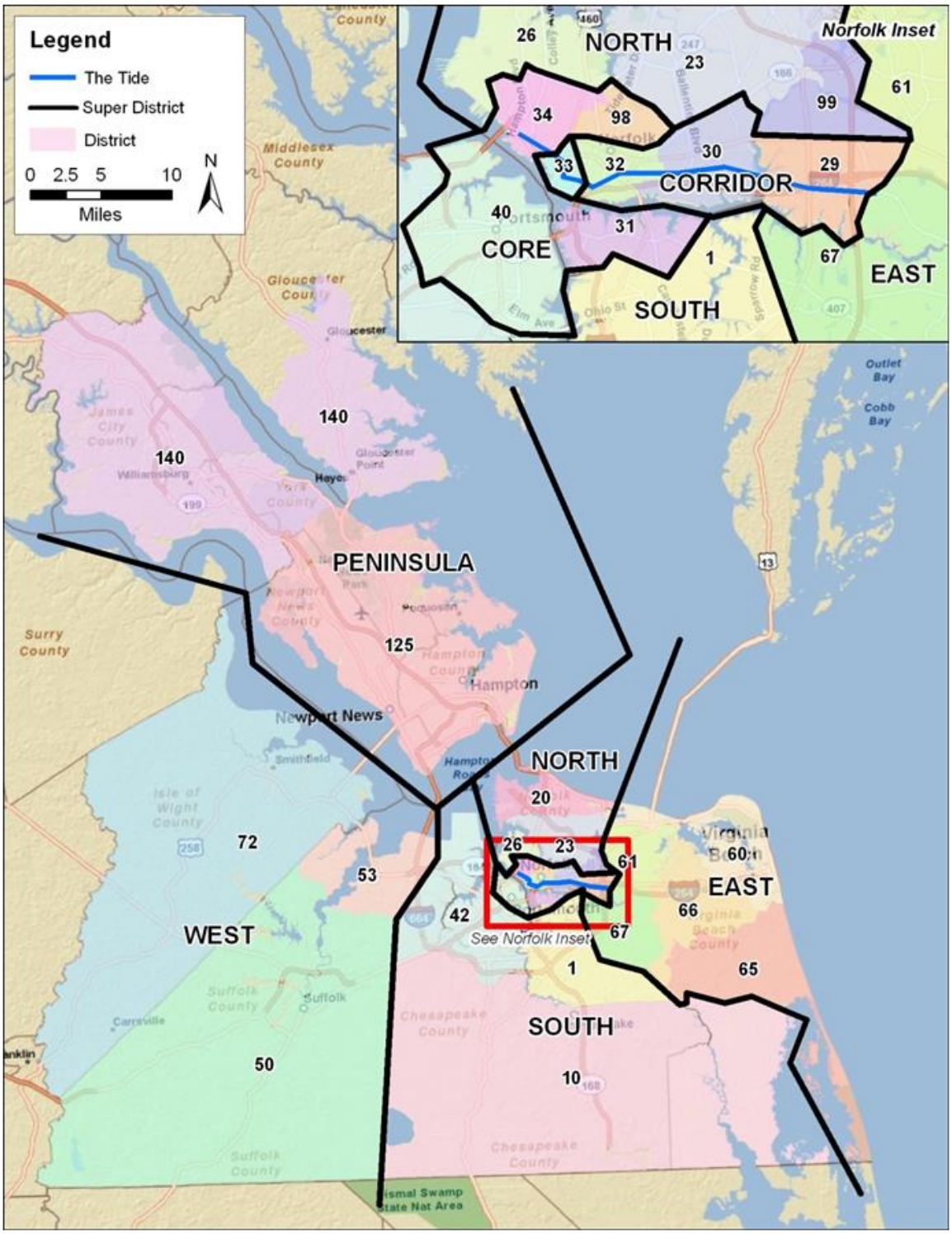
Stations	Observed Weekday Boardings (Aug '11-March'12) (M-F)	LRT skims using Rail mode (Mode 11) + All network fixes Assigned Boardings
EVMC	600	520
Freemason	140	20
Monticello	470	400
MacArthur	700	410
Civic Plaza	375	230
Harbor Park (P)	130	195
NSU	370	300
Ballantine (P)	310	180
Ingleside	70	40
Military Hwy (P)	425	330
Newtown Road (P)	1,010	650
Total	***4600***	***3,275***
Trips assigned to bus only paths	***Not applicable***	***835***
Total	***4,600***	***4,110***

Checking the Study Area Mode Shares in the current VDOT's model

Prior to running the base year model with all the network fixes mentioned above, it was determined that the mode splits to the study area and the trip distribution in the person trip table to the study area be examined first. In order to do that, the entire modeled area was divided into 8 districts as shown in **Figure 9.** The person trip table for the Home Based Work trips was aggregated into these 8 districts. The transit trips from the Pre-Opening run were also aggregated in the same manner and the mode share was computed for all the trips that originated in the study area and destined to the Central Business District (CBD). The same exercise was repeated using the 2000 US Census Journey-to-Work data[19].

[19] The Journey-to-Work data for 2010 has not been released by Census yet. Therefore, comparison was made using the 2000 Census data only.

Figure 10: District System for Mode Split and Person Trips Comparison



Shown in **Table 19** is a comparison of the modeled mode shares to observed shares from Census. As seen, according to the Census, the transit mode shares from the corridor to CBD for work trips is about 14 percent whereas the base year model estimates roughly 20 percent.

Table 19: Transit Mode Split Comparison

	2000 US Census	2011 Base Year Model
From Core district and Corridor district to CBD	14 percent	20 percent

Mode splits for non-work trips could not be compared to any other data. Based on the population data from 2000 and 2010 Census, the region's growth has been very modest, around 6 percent over a ten year period. The transit ridership in the region has fluctuated between 61,000 and 55,000 during this period, according to National Transit Database. That said, the mode split comparison for work trips indicates the model has a tendency to slightly overestimate transit trips from the Core and Corridor districts to CBD .

Checking Distribution of Trips in the TIDE Corridor

For the same districts shown in **Figure 9**, the total person trips for home based work purpose were summarized both from the Census as well as the base year model. The results are summarized in **Table 20.** The results indicated the number of person trips estimated by the model from East district to downtown, East District to the Core district and the East District to the TIDE corridor was significantly lower than the Census trips. It is possible this could be the reason why the initial model runs with all the fixes underestimated boardings at Newton Road and several downstream stations. As a short-term measure, all the person trips from the East district to CBD and the Corridor district were factored up to approximately match the Census distribution. It is recommended that the trip distribution patterns be corrected in the next round of VDOT's model enhancement effort.

Table 20: Comparison of Modeled Person Trips with 2000 Census Trips (CTPP)

	CBD	CORE	CORRIDOR	EAST
CORE				
2011 Model	2,400	6,250	1,500	2,950
2000 CTPP	4,000	10,300	1,900	4,900
CORRIDOR				
2011 Model	1,600	1,800	2,100	3,150
2000 CTPP	1,800	2,450	3,250	3,400
EAST				
2011 Model	**6,450**	**9,800**	**11,350**	151,400
2000 CTPP	**15,600**	**23,350**	**19,600**	239,000

Adding LRT ModalConstants

In order to inform the model some of the unique characteristics of the rail mode (such as its reliability, quality of ride) and to facilitate the calibration of the rail trips without affecting the calibration targets of bus trips, a separate set of LRT modal constants, initially equal to the values of the bus constants, were added to the model. These constants would be adjusted later as described in Section 6.10.3. We defined an LRT path as a transit path included LRT in-vehicle travel time (IVTT) on that path. Therefore, the LRT constants became active only for paths where LRT IVTT was greater than 0 minutes.

Setting Calibration Targets for Rail Trips (for Mode Choice model calibration)

The calibration targets for LRT were created from the TIDE survey. Since an extra trip table for University HBO trips was added to the model after model choice (see section 6.10.4), the targets were reduced by a corresponding amount. So, for calibration purposes, the target for LRT trips in the mode choice was set at 3,840 trips.

Estimation of Modal Constants for LRT Mode

Some travel models contain an automated calibration routine within the programming scripts that can be used to estimate the modal constants by providing the calibration targets. The VDOT model did not contain such a routine. Therefore, the estimation of modal constants for the LRT mode had to be done manually by running the model dozens of times and by adjusting the constants a little at a time until the calibration targets were reached. Initially, the LRT modal constants were set equal to the bus mode. They were modified incrementally until calibration targets were achieved. The final values of LRT constants in the mode choice model that met the calibration target are shown in **Table 21 and 22**. The constants for the Bus mode were not changed from the Pre-opening calibrated values.

Table 21: Values of LRT Mode Choice Constants

Trip Purpose	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	-2.34	-99.00
Peak Home-Based Work trips 1+car	-2.34	-5.69
Peak- Home-Based Other trips 0- car	-3.94	-99.00
Peak Home-Based Other trips 1+car	-3.94	-6.82
Peak Non-Home-Based trips	-3.16	0.00
Off-Peak- Home-Based Work trips 0- car	-1.52	-99.00
Off-Peak Home-Based Work trips 1+car	-1.52	-6.55
Off-Peak- Home-Based Other trips 0- car	-3.13	-99.00
Off-Peak Home-Based Other trips 1+car	-3.13	-7.01
Off-Peak Non-Home-Based trips	-2.92	0.00

Table 22: Values of LRT Mode Choice Constants in Equivalent IVTT Minutes

Trip Purpose	Walk to Transit	Drive to Transit
Peak- Home-Based Work trips 0- car	46.8	1980
Peak Home-Based Work trips 1+car	46.8	113.8
Peak- Home-Based Other trips 0- car	78.8	1980
Peak Home-Based Other trips 1+car	78.8	136.4
Peak Non-Home-Based trips	63.2	0.0
Off-Peak- Home-Based Work trips 0- car	30.4	1980
Off-Peak Home-Based Work trips 1+car	30.4	131.0
Off-Peak- Home-Based Other trips 0- car	62.6	1980
Off-Peak Home-Based Other trips 1+car	62.6	140.2
Off-Peak Non-Home-Based trips	58.4	0.0

University/College Trips in Base Year

During the calibration process, it was determined that College/University trips were underestimated by the trip generation procedure. For example, there were only 50 HBO trip attractions to the zone containing Norfolk State University. This resulted in low station activity at

the NSU Station. To account for this, a HBO college/university trip table was created from the survey records with a total of 716 trips. These trips were mostly to the NSU campus and the Tidewater Community College-Norfolk Campus. These trips were subtracted from the calibration targets and then added to the HBO transit trip tables after mode choice.

Recommended Approach for handling University/College Trips in Forecast Year

The VDOT model is not set up to handle University/College trips properly. Therefore, an alternate approach is being proposed to estimate the University/College trips for the forecast year. It is proposed that the base year University/College trip table estimated from the survey be factored up to the forecast year using the projected student enrollment data. The projected University/College trips will need to be added to the transit trip table produced by the mode choice and the resulting trips will need to be assigned to the future year transit network.

Validation (Post-Opening Condition)

The results of mode choice and assignment model are shown in **Table 23**. The calibrated mode choice model generated a transit trip table that when assigned produced realistic station boardings when compared to actual ridership data. The total line boardings which included the add-on University/College trips from the assignment model was about 4,590 which very closely matched 4,600 average daily boardings observed during August 2011 to March 2012 period.

Table 23: Pre-Opening Model Results after Calibration

Model Statistic	Base Year: 2011 Pre-Opening Network	2011 Post – Opening Network
System wide linked transit trips		
Drive access	1,340	2,050
Walk access	39,780	41,190
Fringe Walk (not part of transit)	1,680	1,780
Fringe transit	950	1,060
Fringe shuttle	2,450	2,630
Total linked trips	**46,200**	**48,710**
Boarding Summary		
Local Bus (rtes 1-121)	45,820	45,340
The NET & Shuttles	3,570	3,920
Max Routes	953	770
Max Rte 960	200	60
TIDE LRT	Not applicable	4,590
Daily boardings (whole system)	**49,200**	**54,680**

Table 24: Transit Assignment from Calibration Model

Stations	Observed Weekday Boardings (Aug '11-March'12) (M-F)	Model Calibrated with LRT constants in Mode Choice
		2011 Assigned Boardings*
EVMC	600	595
Freemason	140	190
Monticello	470	500
MacArthur	700	340
Civic Plaza	375	300
Harbor Park (P)	130	405
NSU	370	340
Ballantine (P)	310	375
Ingleside	70	150
Military Hwy (P)	425	565
Newtown Road (P)	1,010	835
Total	***4,600***	***4,590***

* Includes University/College trips that were added manually from the survey

FTA has always advocated using the same access coverage assumption for all transit modes unless actual survey data indicates otherwise. As illustrated in Section 6.9.1 and 6.10.1, we justified using a Maxwalk of 0.75 miles for LRT stations on the basis of our survey findings, and therefore used a maxwalk of 0.75 for all transit modes. However, as an academic exercise, we also conducted another model calibration by setting the Maxwalk parameter at 0.50 miles for all transit modes and applied the model to simulate TIDE ridership. The results of this exercise are included in Appendix D.

Summary And Conclusions

Initial evaluation of VDOT's new regional travel model indicated the transit component of that model was validated primarily at the systems level. In order to apply the model to the TIDE corridor, a more focused model calibration and validation to the study area was needed. Two major travel surveys, one conducted on the bus system in July 25-29, 2011, just before the opening of the TIDE and another conducted on the rail system in April 19-21, 2012, about 8 months after the opening of the rail, were used for model calibration and validation. The calibration process involved adjusting several parameters in the model. These adjustments included updating centroid connector distances, revising maximum walk access distances to transit centers for buses and rail, lowering transfer penalties, adjusting fares, updating park-and-ride connections and bus run times. Also, a new rail mode was added to the model to facilitate the calibration of the rail system. A simplified procedure was generated to account for University/College trips.

The final calibrated model generated about 4,590 weekday boardings which were very close to the average observed boardings of 4,600 during the period of August 2011 to March 2012. The calibrated model also produced a more accurate distribution of ridership among the eleven rail stations.